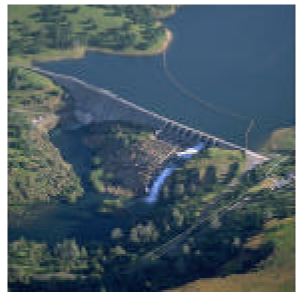
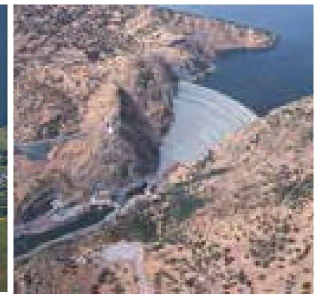
Stanislaus River Water Temperature Model

Lower Stanislaus River

Goodwin



Tulloch



New Melones

Prepared for:

U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
California Department of Fish & Game
Oakdale Irrigation District
South San Joaquin Irrigation District
Stockton East Water District

Prepared by:

AD Consultants
Resource Management Associates, Inc.

March 2002

STANISLAUS RIVER WATER TEMPERATURE MODEL

EXECUTIVE SUMMARY

A group of stakeholders on the Stanislaus River initiated a cooperative effort to develop a water temperature model for the Stanislaus River having recognized the need to analyze the relationship between operational alternatives, water temperature regimes and fish mortality in the Stanislaus River.

Members of the stakeholders group (cost-sharing partners) include the U.S. Bureau of Reclamation (USBR), Fish and Wildlife Service (USFWS), California Department of Fish & Game (CDFG), Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID) and Stockton East Water District (SEWD). In December 1998, the cost-sharing partners retained AD Consultants in association with its subconsultant Research Management Associates, to develop the model and perform a preliminary analysis of operational alternatives. In addition, the cost-sharing partners launched an extensive program for water temperature and meteorological data collection throughout the Stanislaus River Basin, in support of the modeling effort.

The Stanislaus Water Temperature Model is based on the HEC-5Q computer simulation model designed to simulate the thermal regime of mainstem reservoirs and river reaches. The extent of the model includes the New Melones Reservoir, Tulloch Reservoir, Goodwin Pool, and approximately 60 miles of the Stanislaus River from Goodwin Dam to the confluence with the San Joaquin River (SJR).

The objectives of this effort were to develop and calibrate a model capable of simulating the water temperature responses in the Stanislaus River system and to evaluate the impacts of New Melones Reservoir operations on water temperatures. The model is designed to provide a basin-wide evaluation of temperature impacts at 6-hour intervals of alternative conditions such as changes in system operation.

The model development included modifications to the HEC-5Q program code to accommodate several unique attributes, including complex geometry of the submerged (old) dam in New Melones Reservoir and the short residence time and unique diversion characteristics of Goodwin Pool. Only temperature was simulated. The model was calibrated for temperature data collected during the 1990 - 1999 historical period. Tributary stream inflow temperatures were developed from 1999 data. The hydrologic data included two data sets: One- historical flow conditions in the Stanislaus River for the period 1983-1999 and two- simulated flow conditions in the Stanislaus River for the period 1983-1996. The simulated flow conditions were developed using the CALSIM II model. This model allows simulating the operations of New Melones and Tulloch reservoirs, given projected water demands and operational agreements in the basin.

The Stanislaus Water Temperature Model is driven by water temperature objectives at critical points in the river system that would enhance habitat conditions for fall-run Chinook salmon and Steelhead rainbow trout. The temperature objectives were developed by the California Department of Fish and Game which identified three zones

of water temperature conditions: Optimal, sub-lethal and critical. The range of temperatures for each zone varies with time, location and fish type.

The model was used to simulate eleven different cases of Stanislaus River operation. For each case the model estimated the magnitude and duration of water temperature conditions at critical points on the river, and the effect on water supply and storage at New Melones Reservoir.

A CD accompanies this report that contains all simulation results and supporting data referenced in this report. The simulations results may be viewed using the graphical user interface directly from the CD.

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1 INTRODUCTION

A water temperature model based on the HEC-5Q computer program was developed for the Stanislaus River for the purpose of evaluating the impacts of New Melones Reservoir operations on temperature in the Stanislaus River system. The model development included modifications to the HEC-5Q program code to meet the specific requirements of the Stanislaus River system, including addition of the capability to simulate allocation of flows over and through the old Melones dam during low storage periods in New Melones Reservoir.

Daily average flows were based on stream flow and reservoir operation data. Two data sets were used: One - historical conditions in the Stanislaus River for the period 1983-1999, and two- simulated conditions in the Stanislaus River for the period 1983-1996. Inflows to the reservoirs were defined explicitly and subdivided to smaller tributaries based on drainage area. Outflow from the reservoirs were defined explicitly for the historical conditions or computed for the simulated conditions.

Model thermal inputs were developed from observed temperature data on a 2-hour time steps from the major tributaries to the New Melones Reservoir. The data were collected using thermographs placed in key location in the tributaries as part of a basin-wide water temperature-monitoring program that was initiated in 1999. Meteorological conditions were developed from the Modesto CIMIS station hourly data for the period of 1989 – 2000. The model was calibrated using 1990–1999 temperature profile data in New Melones and Tulloch Reservoirs, and temperature time series data below each dam and in the lower Stanislaus River. Calibration involved adjustment of rate coefficients, and diffusion in the reservoirs.

The model was used to simulate eleven different cases of Stanislaus River operation. For each case the model estimated the magnitude and duration of water temperature conditions at critical points on the river, and the effect on water supply and storage at New Melones Reservoir. The driving force behind the different cases is the desire to meet water temperature objectives at critical points in the river system that would enhance habitat conditions for fall-run Chinook salmon and Steelhead rainbow trout. The temperature objectives were developed by the California Department of Fish and Game which identified three zones of water temperature conditions: Optimal, sub-lethal and critical. The range of temperatures for each zone varies with time, location and fish type. The results for the eleven cases are presented in graphical and tabular forms showing the ranking of the cases in accordance with their level of success in achieving the temperature objectives.

1.1 PROJECT OBJECTIVES

The objectives of this modeling study were to develop and calibrate a model capable of simulating the water temperature responses in reservoirs and river reaches of the Stanislaus River system and to investigate various mechanisms for water temperature improvements both through operational and/or structural measures at New Melones Reservoir, Tulloch Reservoir and Goodwin Pool.

An independent appraisal review of the model conducted by Dr. Michael Deas of Watercourse Engineering, Inc. is provided in the Appendix. Dr. Deas assessed the adequacy of the HEC-5Q as tool to model the relationship between operational and water temperature regimes as they potentially relate to fish mortality in the Stanislaus River and the overall success in meeting the project objective.

1.2 REPORT ORGANIZATION

A description of the model is presented in Chapter 2 including a discussion of representation of the physical system and water quality constituents simulation options. Results of the HEC-5Q calibration effort are presented in Chapter 3. Results of the operations study for the period of 1983 through 1996 are presented in Chapter 4. References are provided in Chapter 5. Appendices are provided in Chapter 6. An IBM compatible personal computer (PC) Compact Disc (CD) is contained within this report. The CD includes input data files, model documentation including the model code, selected simulation results and supporting files. A listing of the contents of the CD is provided in the Appendix.

Model inputs contained in the various data sets are described in HEC-5Q users manual (HEC, 2001). Additionally, liberal comments are provided within the data sets to aid in the interpretation of the Stanislaus River Model. Additional information regarding model operation and interpretation of results is provided by the training document (HEC, 1999b).

The HEC-5Q model provides time dependent results at numerous locations within the stream and reservoir components of each basin model. Due to the voluminous results, a graphical user interface (GUI) is provided for viewing and interpreting the model results. The GUI software is compatible with PC computers running under Windows 95, 98, 2000, and NT 4.0. The GUI is described in Exhibit 4 of the HEC-5Q Users Manual.

The calibration and results of the alternative analysis reside on the CD and may be reviewed using the GUI. The CD also contains additional model output and other data and program files that support and augment the report text. Reference is made to the CD throughout this report.

2 MODEL DESCRIPTION

The water quality simulation module (HEC-5Q) was developed so that temperature and conservative and non-conservative water quality constituents could be readily included as a consideration in system planning and management. Using daily average system flows, HEC-5Q computed the distribution of temperature in the reservoirs and in the stream reaches.

HEC-5Q can be used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water quality at specified locations in the system. Examples of applications of the flow simulation model include examination of reservoir capacities for flood control, hydropower and reservoir release requirements to meet water supply and irrigation diversions. The model can be used in applications including evaluation of in-stream temperatures and constituent concentrations at critical locations in the system or examination of the potential effects of changing reservoir operations or water use patterns on temperature or water quality constituent concentrations. Reservoirs equipped with selective withdrawal structures can be simulated using HEC-5Q to determine operations necessary to meet water quality objectives downstream. This option was utilized to operate the New Melones Dam withdrawal facilities and a hypothetical selective withdrawal structure (TCD – temperature control device).

HEC-5Q can be used to simulate concentrations of various combinations of the following water quality constituents, many of which may be coupled with other water quality constituents.

- Temperature
- TDS or conservative tracer
- Electrical Conductivity (EC)
- Ammonia (NH_3) – Nitrogen
- Nitrate (NO_3) - Nitrogen
- Phosphate (PO_4) – Phosphorus
- Carbon dioxide (CO_2) - Carbon
- Phytoplankton
- Dissolved oxygen
- Dissolved organic material (DOM)
- Particulate organic material (TSS)
- Benthic algae
- Chloride
- Alkalinity
- Total inorganic carbon and pH
- Coliform bacteria
- 3 user-specified conservative constituents
- 3 user-specified non-conservative constituents
- Water column and sediment dissolved organic chemicals
- Water column and sediment heavy metals
- Water column and sediment dioxins and furans
- Water column and sediment iron, manganese and sulfur

The HEC-5Q model used in the Stanislaus River analysis utilized only temperature and the conservative tracer (for mass continuity checking). A brief description of the processes affecting these two parameters and other water quality parameters of a typical comprehensive water quality model application is provided below. With the exception of benthic algae, all of these parameters are assumed passively transported by advection and diffusion. All rate coefficients regulating the parameter kinetics are first order and temperature dependent. Refer to the HEC-5Q users manual (HEC, 2001a) for a more complete description of the water quality relationships of the model.

Temperature

The external heat sources and sinks that were considered in HEC-5Q were assumed to occur at the air-water interface, and at the sediment-water interface. The method used to evaluate the net rate of heat transfer utilized the concepts of equilibrium temperature and coefficient of surface heat exchange. The equilibrium temperature is defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere was zero. The coefficient of surface heat exchange is the rate at which the heat transfer process progresses. All heat transfer mechanisms, except short-wave solar radiation, were applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures several meters below the surface. The depth of penetration is a function of adsorption and scattering properties of the water as affected by particulate material (i.e. phytoplankton and suspended solids). The heat exchange with the bottom is a function of conductance and the heat capacity of the bottom sediment.

Conservative parameter / tracer

The conservative parameter is unaffected by decay, settling, etc. This parameter was used to check mass continuity by setting the quality of all inflows to a constant value and then checking to see that the simulation results did not deviate from that value.

Ammonia – Nitrogen (NH3)

Ammonia is a plant nutrient and is consumed with phytoplankton and benthic algae growth. The remaining ammonia sink is decay. Sources of ammonia include phytoplankton and benthic algae respiration, TSS and DOM decay, and aerobic and anaerobic release from bottom sediments.

Nitrate – Nitrogen (NO3)

Nitrate is a plant nutrient and is consumed with phytoplankton and benthic algae growth. The remaining nitrate sink is denitrification associated with suboxic processes that occur at low dissolved oxygen levels. Decay of ammonia provides a source of nitrate (intermediate nitrite formation is considered rapid relative to the model time step and was included as a component of NO_3).

Phosphate – Phosphorus (PO4)

Phosphorus was the third plant nutrient considered in the model and is consumed with phytoplankton and benthic algae growth. Phosphates tend to sorb to suspended solids and are subject to loss by settling. Sources of phosphorus include phytoplankton and benthic algae respiration, TSS and DOM decay, and aerobic and anaerobic release from bottom sediments.

Carbon Dioxide – carbon (CO2)

Carbon is the final plant nutrient considered in the model and is consumed with phytoplankton and benthic algae growth. Sources of carbon dioxide include phytoplankton and benthic algae respiration, TSS and DOM decay and aerobic and anaerobic release from bottom sediments. Exchange of CO_2 at the water surface is a function of the ambient and saturation concentrations and surface exchange (reaeration) rate that is determined by wind speed in reservoirs and hydraulic characteristics in streams. Carbon dioxide is a component of total inorganic carbon (TIC) and the CO_2 concentration is calculated as a function of alkalinity and pH. Refer to the alkalinity, TIC and pH section below for further details of the CO_2 computations,

Phytoplankton

Photosynthesis acts as a phytoplankton source that is dependent on the concentration of phosphate, ammonia, nitrate and carbon dioxide. Photosynthesis is therefore a sink for these nutrients. Conversely, phytoplankton respiration releases phosphate, ammonia and CO2. Phytoplankton is an oxygen source during photosynthesis and an oxygen sink during respiration. Phytoplankton growth rates are a function of the limiting nutrient (or light) as determined by the Michaelis-Menten formulation. Respiration, settling and mortality are phytoplankton sinks.

Dissolved Oxygen (DO)

Exchange of dissolved oxygen at the water surface is a function of the surface exchange (reaeration) rate that is determined by wind speed in reservoirs and hydraulic characteristics in streams. Phytoplankton and benthic algae photosynthesis is a source of DO. Sinks for DO include ammonia, DOM and TSS decay, phytoplankton and benthic algae respiration, and benthic uptake.

Dissolved and Particulate Organic Material (DOM and TSS)

Sources of DOM and TSS include a component of phytoplankton and benthic algae respiration and mortality. DOM and TSS sinks include decomposition to phosphate, ammonia and CO_2. TSS is also subject to settling. DOM is partitioned into labile and refractory components having different decay and transformation characteristics.

Inorganic Particulate Material

Inorganic particulate material is conservative except for settling. It impacts light attenuation, affecting reservoir temperature, and phytoplankton and benthic algae growth.

Benthic Algae

Benthic algae biomass is not explicitly modeled, but is input as a spatially and temporally varying benthic algae standing crop. Growth of benthic algae produces DO, and consumes PO_4, NH_3, NO_3 and CO_2. Respiration mortality of benthic algae consumes DO, and releases PO_4, NH_3, CO_2, DOM, and TSS. Growth rate and related nutrient uptake rates are a function of ambient temperature and nutrient concentration.

Alkalinity, Total Inorganic Carbon (TIC) and pH

Alkalinity is considered conservative. Total inorganic carbon includes all components of the carbonate system including CO_2 (i.e., TIC = [CO2-C] + [CO3-C]).

The sources and sinks are described in the CO_2 section. The component concentrations are computed according to equilibrium theory considering $CO3^{--}$, $HCO3^{-}$, CO2, OH^{--} and H^{+}. The pH reflects the molar H^{+}.

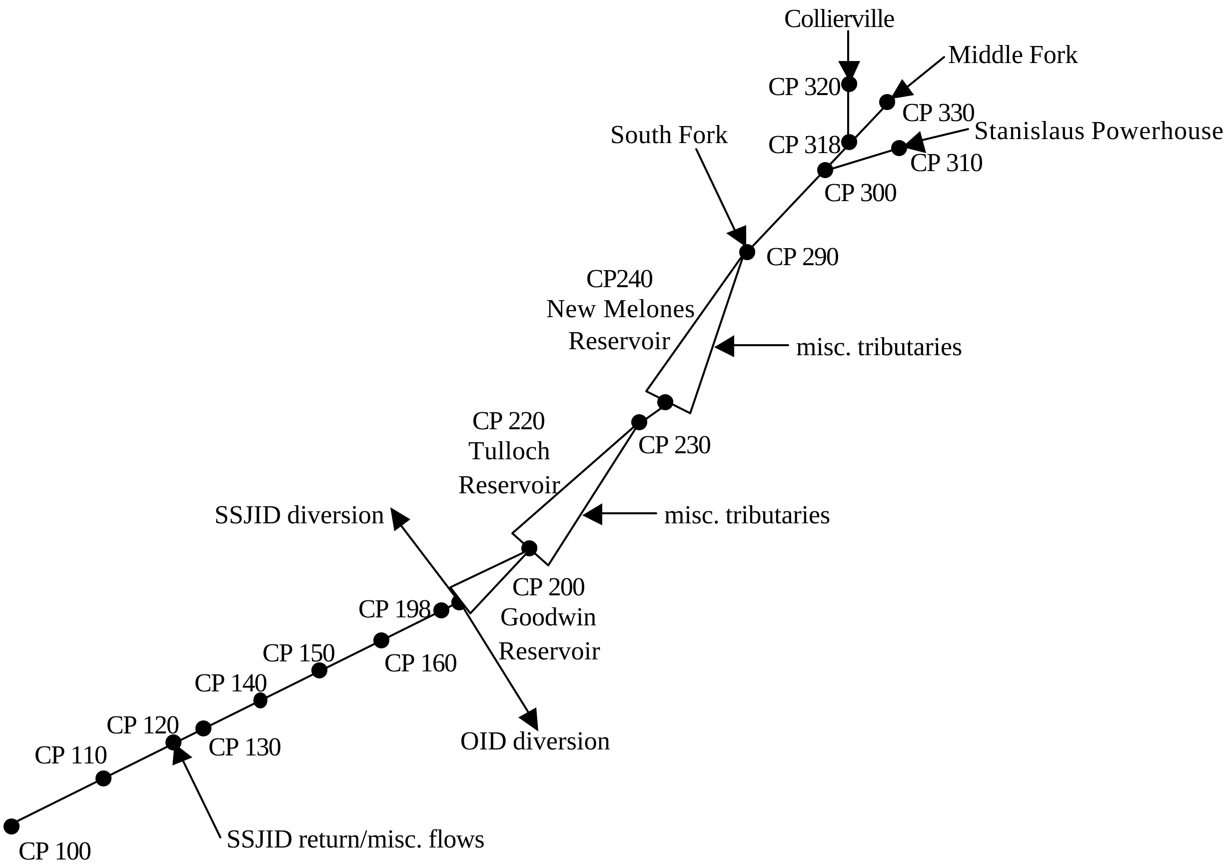
2.1 MODEL REPRESENTATION OF THE PHYSICAL SYSTEM

For application of HEC-5 and HEC-5Q, rivers and reservoirs comprising the Stanislaus River system were represented as a network of reservoirs and streams and discretized into sections within which flow and water quality were simulated. Control points (CP) represent reservoirs and selected stream locations. Flows, elevations, volumes, etc. were computed at each control point.

Figure 2-1 provides a schematic representation of the HEC-5 model. Arrows indicate points of defined inflow and withdrawals.

In HEC-5, flows and other hydraulic information are computed at each control point. Within HEC-5Q stream reaches and reservoirs were partitioned into computational elements to compute spatial variations in water temperature between control points. Within each element, uniform temperature was assumed, therefore the element size determines the spatial resolution. The model representation of streams and reservoirs is summarized in Section 2.2.

Figure 2-1 Schematic of HEC5 model of the Stanislaus River system.



2.2 MODEL REPRESENTATION OF RESERVOIRS

For water quality simulations, New Melones Reservoir and Tulloch Reservoir were geometrically discretized and represented as vertically segmented water bodies with approximately 2' thick layers. Goodwin Reservoir was represented as vertically layered and longitudinally segmented with nine segments, and 5 layers each representing 1/5 of the cross-sectional area. A description of the different types of reservoir representation follows.

Vertically Segmented Reservoirs

Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. The aggregate assemblage of layered volume elements is a geometrically discretized representation of the prototype reservoir. The geometric characteristics of each horizontal slice are defined as a function of the reservoir's area-capacity curve. Within each horizontal layer (or 'element') of a vertically segmented reservoir, the water is assumed to be fully mixed with all isopleths parallel to the water surface both laterally and longitudinally. External inflows and withdrawals occur as sources or sinks within each element and are instantaneously dispersed and homogeneously mixed throughout the layer from the headwaters of the impoundment to the dam. Consequently, simulation results are most representative of conditions in the main reservoir body and may not accurately describe flow or quality characteristics in shallow regions or near reservoir banks. It is not possible to model longitudinal variations in water quality constituents using the vertically segmented configuration.

The allocation of the inflow to individual elements is based on the relative densities of the inflow and the reservoir elements. Flow entrainment is considered as the inflowing water seeks the level of like density.

Vertical advection is one of two transport mechanisms used in HEC-5Q to simulate transport of water quality constituents between elements in a vertically segmented reservoir. Vertical transport is defined as the inter-element flow that results in flow continuity.

An additional transport mechanism used to distribute water quality constituents between elements is effective diffusion, representing the combined effects of molecular and turbulent diffusion, and convective mixing or the physical movement of water due to density instability. Wind and flow-induced turbulent diffusion and convective mixing are the dominant components of effective diffusion in the epilimnion of most reservoirs.

The outflow component of the model incorporates a selective withdrawal technique for withdrawal through a dam outlet or other submerged orifice, or for flow over a weir. The relationships developed for the 'WES Withdrawal Allocation Method' describe the vertical limits of the withdrawal zone and the vertical velocity distribution throughout the water column.

The New Melones Dam has selective withdrawal capability. Tulloch and Goodwin Dams are equipped with single low-level flood control outlets. Each of the reservoirs have uncontrolled emergency spillways. Flows were assigned to the selective withdrawal and low-level outlet first, with excess to the spillways.

Longitudinally Segmented Reservoirs

Longitudinally segmented reservoirs are represented conceptually as a linear network of a specified number of segments or volume elements. Length and the relationship between width and elevation characterize the geometry of each reservoir segment. The surface areas, volumes and cross-sectional areas are computed from the width relationship.

Longitudinally segmented reservoirs can be subdivided into vertical elements, with each element assumed fully mixed in the vertical and lateral directions. Branching of reservoirs is allowed. For reservoirs represented as layered and longitudinally segmented, all cross-sections contain the same number of layers and each layer is assigned the same fraction of the reservoir cross-sectional area. Therefore, the thickness of each element varies with the width versus elevation relationship for each element. The model performs a backwater computation to define the water surface profile as a function of the hydraulic gradient based on flow and Manning's equation.

External flows such as withdrawals and tributary inflows occur as sinks or sources. Inflows to the upstream ends of reservoir branches are allocated to individual elements in proportion to the fraction of the cross-section assigned to each layer. Other inflows to the reservoir are distributed in proportion to the local reservoir flow distribution. External flows may be allocated along the length of the reservoir to represent dispersed non-point source inflows such as agricultural drainage and groundwater accretions.

The longitudinally segmented reservoir, Goodwin Reservoir, contains five layers of equal cross-sectional area.

Vertical variations in constituent concentrations can be computed for the layered and longitudinally segmented reservoir model. Mass transport between vertical layers is represented by net flow determined by mass balance and by diffusion.

Vertical flow distributions at dams are based on weir or orifice withdrawal. The velocity distribution within the water column is calculated as a function of the water density and depth using the WES weir withdrawal or orifice withdrawal allocation method.

A uniform vertical flow distribution is specified at the upstream end of each reservoir. Velocity profiles within the body of the reservoir may be calculated as flow over a submerged weir or as a function of a downstream density profile. Submerged weirs or orifices may be specified at the upstream face of the dams. Linear interpolation is performed for reservoir segments without specifically defined flow fields.

2.2.1 New Melones Reservoir

Of special interest are the representation of New Melones Reservoir and the impacts of the old dam on the flow and thermal regime of the reservoir and reservoir release temperatures.

Figure 2-2 shows a schematic representation of the New and Old Melones Dams. Flow allocation at different reservoir levels is discussed below, namely:

- Flow allocation when using the existing New Melones Dam primary (power) outlet;
- Flow allocation when in transition from primary outlet operations to the low level out with the water surface above the old dam spillway invert;
- Flow allocation below old dam spillway invert.

As the reservoir fills, the flow allocation logic applies in reverse.

<u>Flow Allocation Using New Melones Dam Primary Outlet (Water Surface Elevation > 785 Feet)</u>

The primary intake for New Melones Dam is at elevation 760 feet, and the pool elevation for hydropower production is approximately 785 feet. The code has been modified to limit the lower extent of the withdrawal envelope (calculated with the WES method (USACE-HEC 1986)) to the top of the old dam for elevations above 785 feet (785 feet to full pool, approximately 1088 feet). Below 785 feet the low-level outlet is used due to operational constraints.

During the 1990-2000 calibration period, water is released from the low-level outlet during the following four periods.

- 30 September 1991 – 27 November 1991
- 01 July 1992 – 04 January 1993
- 22 September 1994 – 31 October 1994
- 06 October 1997 – 28 January 1998

Only the July 1, 1992 through January 4, 1993 period was due to low lake levels. The other three periods of low-level withdrawal were due to other operational considerations.

Flow Allocation when in Transition from Primary Outlet Operations to Old Dam Spillway Invert (Water Surface Elevation 785 to 723 Feet)

When water levels in New Melones Reservoir drop below 785 feet, reservoir withdrawals are no longer made from the primary intake (elevation 760 feet), but instead are drawn from the low-level outlet (elevation 543 feet). For water levels from 785 feet to 728 feet (five feet above old dam spillway invert), all water is assumed to pass over the crest and/or over the spillway of the old dam. These flows are represented with an orifice equation where the area and elevation (relative to the old dam spillway elevation) is a function of the approach velocity. The release temperature is computed directly using the WES withdrawal method. As flow increases, the dimensions of the orifice (area and centerline elevation) are increased to maintain an approach velocity of 0.1 feet per second.

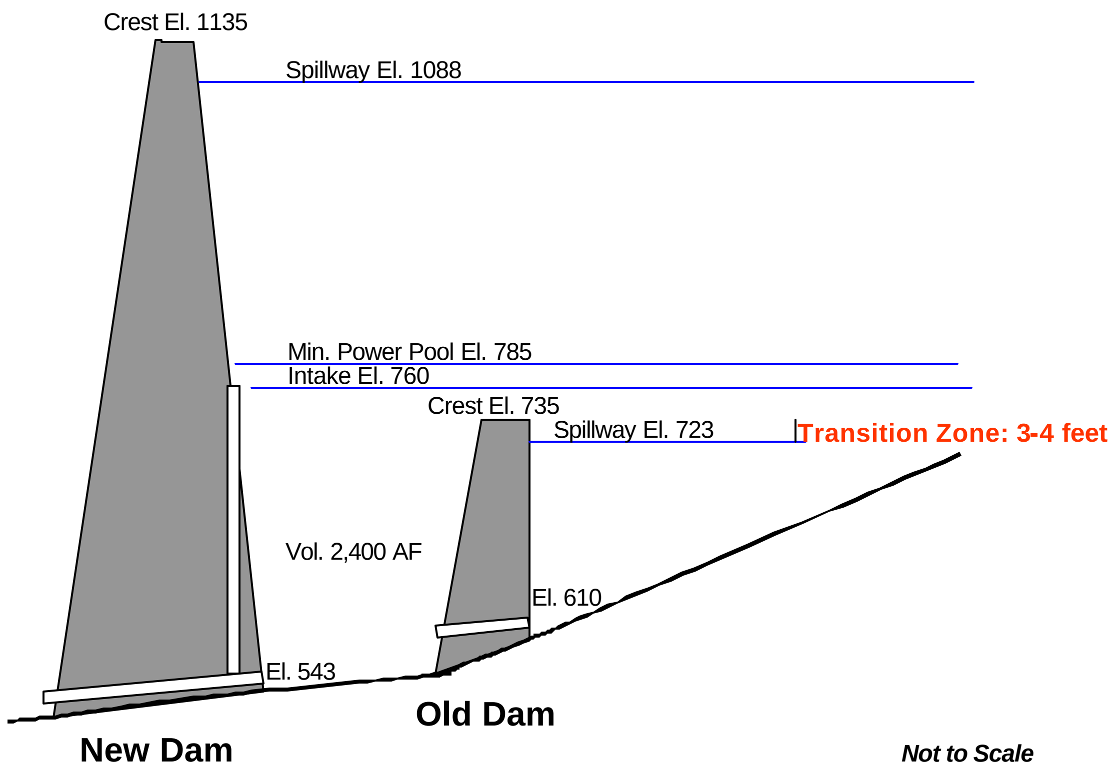
When the reservoir level drops to within five feet of the old dam spillway crest the model transitions from flow passing solely over the old dam to a combined passage: both over the old dam spillway and through the low-level outlet in the old dam. The total flow transitions linearly from all flow passing over the top of the dam at five feet above the spillway invert to all of the flow passing through the old dam low-level intake when the reservoir level reaches the spill invert. This approach assumes that the old dam power outlet is open prior to surfacing of the old dam spillway.

The inter-dam region (volume) is not explicitly modeled. It is a small quantity of water when the reservoir drops to the crest elevation of the old dam: approximately 2400 acre-feet. During the transition period, warm waters flow over the top of the old dam and cooler waters flow through the low-level intake. The New Melones Reservoir release temperature is calculated using a mass balance; water that passes over the dam and that which passes through the low-level intake are assumed mixed completely and instantaneously in proportion to their total quantity.

Flow Allocation Below Old Dam Spillway Invert (Water Surface Elevation < 723 feet)

Once below the old dam spillway invert, all flows are passed through the low-level outlet and assigned a withdrawal envelope according to the WES withdrawal approach (USACE-HEC 1986) and the physical characteristics of the old dam power intake.

Figure 2-2 Schematic representation of New and Old Melones Dams.



2.3 MODEL REPRESENTATION OF STREAMS

In HEC-5Q, a reach of a river or stream is represented conceptually as a linear network of segments or volume elements. The length, width, cross-sectional area and a flow versus depth relationship characterize each element. Cross-sections are defined at all control points and at intermediate locations when data are available. The flow versus depth relation is developed external to HEC-5Q using available cross-section data and appropriate hydraulic computation. Linear interpolation between input cross-section locations is used to define the hydraulic data for each element.

For the Stanislaus River, three river reaches are modeled: upstream of New Melones Reservoir, between New Melones Dam and Tulloch Reservoir, and from Goodwin Dam to the confluence with the San Joaquin River. Upstream of New Melones, the river length is a function of New Melones elevation so that heat exchange in the normally inundated old river channel can be simulated. Downstream of New Melones, Corp of Engineers cross-sections, field reconnaissance, and aerial photographs were used to define the geometry of the stream reaches A total of 83 cross sections were utilized to define the river geometry.

It was inferred from the initial temperature simulation results and ambient data at Ripon that the thermal response of the River below Goodwin Reservoir changed as a result of the high flows of January 1998. Prior to January 1998, less heating is evident in the river relative to that observed in the stream temperature data and in the computed temperatures after January 1998. It was our conclusion that scouring flows during the high flow event created a channel (in the lower river) with more rapid heating at low to moderate flows (lower velocities and/or less riparian shading). The cross section adjustments were made as part of the calibration exercise.

Flow rates are calculated at stream control points by HEC-5 using one of several available hydrologic routing methods. For the Stanislaus River project, all flows were routed using specified routing. Within HEC-5, incremental local flows (i.e., inflow between adjacent control points) are assumed deposited at the control point. Within HEC-5Q, the incremental local flow may be divided into components and placed at different locations within the stream reach (i.e., that portion of the stream bounded by the two control points). The diversions (demands) are allocated to individual control points within the river reaches or reservoirs. A flow balance is used to determine the flow rate at element boundaries.

Inflows or withdrawals may include any point or non-point flow. Distributed flows such as groundwater accretions and non-specific agricultural return flows are defined on a rate per mile basis.

For simulation of water quality, the tributary locations and associated water quality are specified. To allocate components of the diversion flow balance, HEC-5Q performs a calculation using any specified withdrawals, inflows, or return flows, and distributes the balance uniformly along the stream reach. Once inter-element flows are established, the water depth, surface width and cross sectional area are computed at each element boundary, assuming normal flow and downstream control (i.e., backwater). For this study, there were no return flows other than groundwater. Stream elements were approximately one mile long. The river elements above New Melones varied with reservoir stage, expanding in length under low storage conditions and contracting at high storage levels.

2.4 HYDROLOGIC & WATER QUALITY BOUNDARY CONDITIONS

HEC-5Q requires that flow rates and water quality be defined for all inflows. Inflow rates may be defined explicitly or as a fraction of the incremental local flow to the control point as defined by HEC-5. The flow fraction method was used for all stream inflows.

Table 2-1 lists fractions of the total incremental inflow assigned to each of the individual tributaries to each reservoir and stream reach.

Water temperature was simulated by HEC-5Q using tributary stream inflow temperatures developed from 1999 data. Table 2-2 summarizes the average, maximum and minimum water temperatures, and the methods used to define the temperature relationships for each tributary inflow. The same relationships were used to define temperatures for all years, and no attempt was made to evaluate the appropriateness of the relationships during other years. Temperatures are defined using a harmonic curve (Figure 2-3), seasonally (Figure 2-4), or as a function of equilibrium temperature using meteorological data (Figure 2-5). The seasonal boundary conditions are specified based on data from one of four tributaries, however only 6 months of data were available, which is not sufficient for developing a generalized seasonal relationship. This data limitation is a weakness in the model.

Table 2-1 Incremental inflow assignment

Tributary	Method	Percent Net Inflow to New Melones*
Stanislaus PH above New Melones	Actual	NA
Collierville PH above New Melones	Actual	NA
Middle + North Forks above new Melones	Computed	60%
South Fork above New Melones	Computed	25%
Other inflows to New Melones	Computed	15%
Inflows to Tulloch	Computed (mass balance on Tulloch)	NA
South San Joaquin Canal Spill	Computed (Ripon flow -Goodwin release)	NA

* Net Inflow to New Melones Equals: Total Inflow minus PH Flow (Stanislaus + Collierville)

Table 2-2 Average, maximum, and minimum inflow temperatures.

Tributary	Method	Water Temperature (degrees F)		
		Average	Minimum	Maximum
Stanislaus PH above New Melones	Seasonal -1999 Stanislaus PH forebay data	48.9	41.9	58.1
Collierville PH above New Melones	Seasonal - 1999 Collierville tailrace data	49.1	41.0	64.4
Middle Fork above New Melones	Seasonal - 1999 Middle Fork data	51.9	42.8	66.2
South Fork above New Melones	Function of meteorological data	52.0	43.7	68.0
Other inflows to New Melones	Function of meteorological data	61.7	42.8	75.2
Inflows to Tulloch	Function of meteorological data	63.9	42.8	75.2
Groundwater	Harmonic - Calibration variable	57.1	50.0	64.4
South San Joaquin Canal Spill	Seasonal - Lower river Data	58.1	48.2	69.8

Figure 2-3 Harmonic temperature relationship.

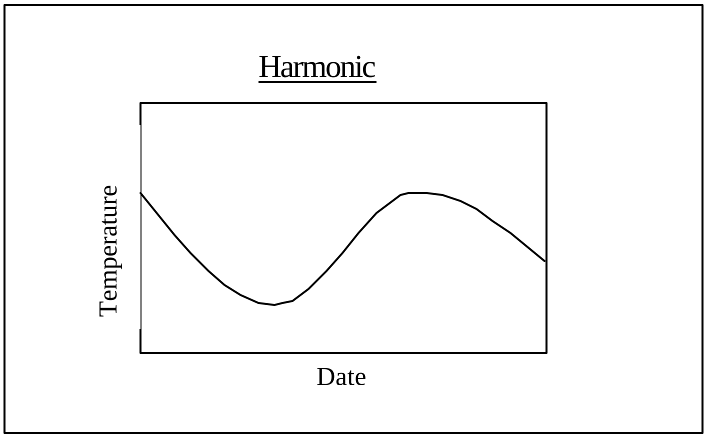


Figure 2-4 Seasonal temperature relationship.

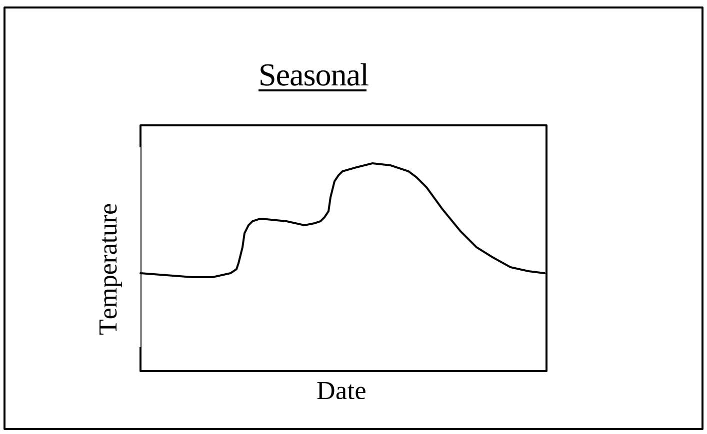
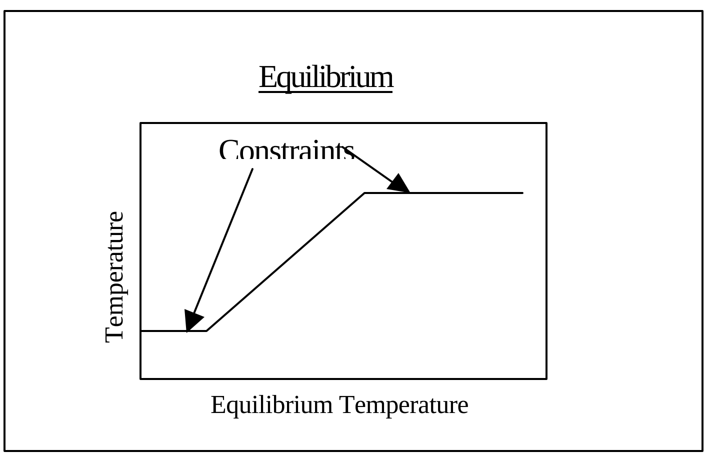


Figure 2-5 Equilibrium temperature relationship.



2.5 METEOROLOGICAL DATA

Specification of water surface heat exchange data requires designation of meteorological zones within the study area. Each control point within the system or sub-system used in temperature or water quality simulation must be associated with one of the defined meteorological zones. Meteorological zones represent hourly data from the Modesto CIMIS station for the period of 1989 - 2000. Where appropriate, atmospheric conditions are adjusted to reflect riparian vegetation shading or increased wind speed over open water.

Meteorological data for the 1983 – 1988 period were developed by extrapolation of the CIMIS data based on daily USWS maximum and minimum air temperature and daily precipitation data at Modesto. A relationship was developed between the maximum and minimum temperatures and hourly data from the 1989 – 1999 period. The hourly CIMIS record with the temperature extreme closest to the maximum and minimum from the 1983 - 1988 data was assigned for each day of the 1983 – 1988 period. Candidate CIMIS records were within 2 days before or after the 1989-1999 date, thus up to 5 days from each of the 11 years of CIMIS data (a total of 55 days) were available for assignment to each day of USWS data

For all simulations, hourly air temperature, wind speed, relative humidity, and cloud cover were used to compute equilibrium temperatures and exchange rates at 6-hour intervals for input to HEC5Q. Heat exchange was adjusted for individual stream sections to reflect environmental conditions such as wind speed, riparian shading, and open or sheltered water bodies.

Three meteorological zones were used in the Stanislaus River model. The adjustments to the meteorological data are as follows.

- New Melones and Tulloch Reservoirs: Double the wind speed
- Goodwin Canyon: No adjustments
- Lower Stanislaus River: Seasonal riparian shading

3 MODEL CALIBRATION

HEC-5Q was calibrated using water quality field observations in New Melones Reservoir, Tulloch Reservoir, and Goodwin Reservoir and at several stations in the Stanislaus River during the 1990 – 1999 period. The following data sets were utilized.

- 1990 – 1994, and 1998 - 1999 temperature profile data in New Melones Reservoir.
- 1990 – 1994, and 1998 - 1999 temperature profile data in Tulloch Reservoir.
- 1990 – 1993, and June 1999 – January 2000 temperature time series data below Goodwin Dam.

- June 1999 – January 2000 temperature time series data at Knights Ferry, Orange Blossom Bridge, Oakdale Recreation, Riverbank and above the confluence with the San Joaquin River.
- June 1993 – February 2000 temperature time series data at Ripon.

The hydrology, meteorology, and inflow water quality conditions described in Chapter 2 were assumed.

The intent of the model calibration exercise was to demonstrate that the model adequately represents the thermal responses of the prototype stream and reservoir system adjusted to minimize the differences between the computed and observed data.

The final water quality coefficients of the calibrated models are listed in the model output on the CD that accompanies this report.

The results of the calibration effort are presented as plots of computed versus observed values using various formats. The final results of the calibration effort may be viewed using the graphical user interface (GUI). The GUI is described in Exhibit 4 of the HEC-5Q Users Guide.

The following sections provide a brief discussion of the calibration results for reservoirs and streams. Station locations are shown in Figure 3-1. The discussion proceeds by data set as listed above. Note that results from 1998 and later are plotted separately from the earlier results due to the change in channel geometry.

3.1.1 Reservoir Temperature Calibration Results

Computed and observed vertical reservoir temperature profiles are plotted in Figure 3-2 – Figure 3-22 for dates during 1990 – 1994 and 1998 – 1999. No profile data were available for 1995 – 1997.

The model generally does an excellent job of reproducing the thermal structure in New Melones Reservoir, as shown in Figure 3-2 –Figure 3-11. Most results for 1990 – 1994, and 1998 are within approximately 1° to 2° F of observed values. Computed profiles show slightly more stratification with cooler temperatures in the hypolimnion and/or warmer temperatures at the surface. This is especially apparent on October 16, 1991 (Figure 2-1) when computed surface temperatures are as much as 3° F warmer than observed at the surface, and temperatures are nearly 3° F cooler near the bottom. The differences between the computed and observed bottom temperatures are impacted by the inflow temperatures. A maximum difference of only 3° F indicates that the 1999 data provide a reasonable approximation of the inflow temperatures for other years. The 3° F difference at the surface is most likely due to assumed meteorological conditions. Again, a maximum difference of only 3° F indicates that the extrapolation of Modesto CIMIS data to New Melones provides a reasonable approximation of the actual heat exchange processes. It should also be noted that near surface temperatures have very little impact on withdrawal temperatures unless the outlet is within hypolimnion,

During August through October 1992 one of the stations for which observed data are plotted is the “Mid Dams” station. This station is located in between the new and old dams. Temperatures are much warmer than at the other stations during August and September because the mid dam area is filled with warm surface water that is flowing over the top of the old dam. In October 1992, flow over the top of the old dam ceased and all of the flow entering the mid dam area came from the cooler bottom waters of the reservoir, passing through the low level outlet of the old dam, resulting in cooler temperatures at the Mid Dam station. The specialized coding within the model takes this phenomenon into consideration when computing the outflow temperatures below New Melones Dam.

Results for 1999 are within approximately 1° F on all sample dates. Results for this period are better than for the earlier years simulated, because inflow temperature data were available for 1999 and used directly, whereas for the other years, inflow temperatures were estimated from the 1999 data. Observed values plotted during this period for the "Camp Nine" station are much cooler than the other stations because Camp Nine is located in a shallow area where cold inflow has not mixed in the reservoir. The similarity of the observed data at all other location is clear evidence that the one-dimensional assumption is appropriate for the main body of the reservoir.

Computed and observed temperature profiles for Tulloch Reservoir are plotted in Figure 3-12 – Figure 3-18. Results from 1990 – 1994 from January through about September show computed values as much as 4° F cooler than observed values. This is more a reflection of a timing lag in the model than a discrepancy in temperature magnitude. As shown in the plot of computed and observed temperature time series for 1990 - 1993 below Goodwin Dam in

Figure 3-19, computed temperatures are slower to rise from January through September of each year, compared with observed data. The computed temperatures lag the observed by about a week. This lag below Goodwin Dam has been passed down from Tulloch Reservoir. During the summer of 1992 when New Melones Dam operations resulted in a summertime drop in water temperature and subsequent re-warming, the model results below Goodwin Dam were in time with observed data, and thus the computed vertical temperature profile in Tulloch Reservoir in August 1992 was within approximately 1° F of observed data. The December 1991 computed profile is in good agreement with observed data (the only winter profile measurement available), and computed profiles during October of each year are generally within 2° F of observed data.

Computed Tulloch Reservoir temperature profiles for 1998 – 1999 are generally within 2° F of observed data, except during the summer months when computed temperatures are as much as 3° F cooler than observed. The differences between computed and observed temperatures occur at the surface and/or the thermocline. Computed bottom temperatures are within less than 1° F of observed in each of the profiles for this period.

The timing lag seen in

Figure 3-19 below Goodwin Dam is reflected in the computed versus observed temperature plot for the same location in Figure 3-20. Although the best linear fit of the data result in an equation that does not stray far from a one-to-one relationship, the lag results in an R2 value of 0.89 indicating scatter in the data. Additional computed and observed temperature time series below Goodwin Dam for June 1999 – January 2000 are plotted in Figure 3-21. Excellent agreement is achieved between computed and observed, and the time lag seen in the 1990 – 1993 plot is not a problem here, explaining why the 1998 – 1999 Tulloch Reservoir vertical profile results are better than the earlier profile results. The resulting computed versus observed temperature plot for 1999 below Goodwin Dam in Figure 3-22 shows a best linear fit very near a one-to-one correlation, with an R2 value of 0.95. The computed versus observed temperature plots are explained in greater detail in the following section.

3.1.2 Stream Temperature Calibration Results

Computed and observed maximum, average and minimum temperature time series, and computed versus observed temperatures are plotted in Figure 3-22 – Figure 3-30 and Figure 3-33 – Figure 3-36 for January 1999 – February 2000 at six locations along the Stanislaus River: Knights Ferry, Orange Blossom, Oakdale, Riverbank, Ripon and at the confluence of the Stanislaus and San Joaquin Rivers. Similar plots are also available for June 1993 – December 1998 at Ripon in Figure 3-31and Figure 3-32. The time series plots show that an excellent representation of the average temperatures, diurnal variation, and daily and season variation is achieved at each location. The emphasis of the temperature calibration was on achieving the best representation of average temperatures, as only averages were used in the alternatives analysis. The diurnal range of computed values are plotted at 6PM and 6AM, respectively, which may not be the times of absolute maximum and minimum temperatures. Therefore, the diurnal range of observed values may be slightly greater than that plotted for the computed results.

In the computed versus observed temperature plots, an exact match between computed and observed data would result in an equation with a slope of 1 and an intercept of 0, or y = 1x, and an R2 value of 1. Discrepancies between computed and observed data result in non-zero intercept values and slopes greater than or less than 1. Differences between data points and the line described by the equation result in an R2 value less than 1. Two equations are shown on each plot in Figure 3-23 – Figure 3-36: the upper equation is the best linear fit to the data, and the lower equation is the best linear fit with the intercept set at 0. At all locations R2 values for both equations are 0.94 or higher and the R2 values for one equation are not significantly different from that of the other equation at any location, indicating that forcing the intercept to 0 does not result in a poor fit of the data. The largest differences between R2 values for the two equations are at Oakdale Recreation (Figure 3-28) and Orange Blossom Bridge (Figure 3-26). At these locations the slopes for the first equations are less than 0.9 and the intercepts are at about 6. These equations indicate a tendency for the lower computed temperatures to be slightly higher than observed, and the higher computed temperatures to be slightly lower than observed. This can be seen in the time series as well. However, the difference between the two R2 values at each of these locations is less than 0.02 so the discrepancies are not of great importance. With the intercept set at zero, all plots have a slope between 0.99 and 1.01.

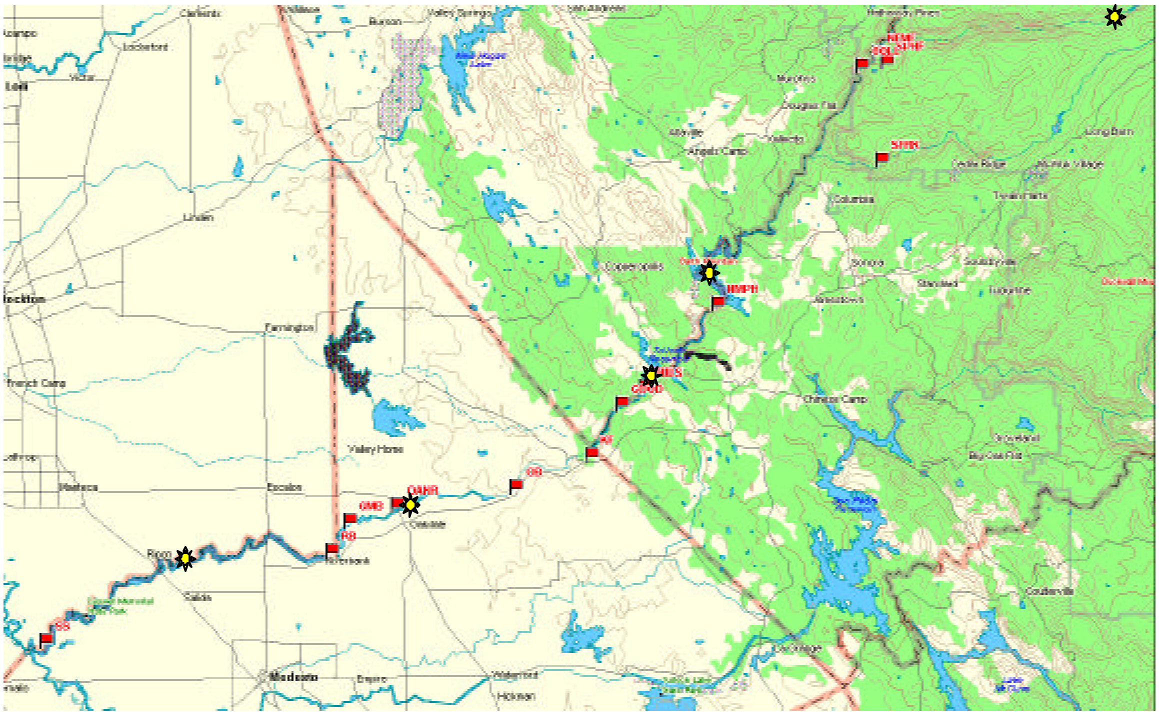
Table 3-1 summarizes the 1999 results for each location. The averages of the observed and computed values used in the computed versus observed plots are listed, along with the root mean squared error.

These calibration results are preliminary. Additional data is being collected which will be used to improve the final calibration results.

Table 3-1 Average observed and computed water temperatures, and associated root mean squared error at seven stations on the lower Stanislaus River for 1999.

Location	**Water Temperature (degrees F)**		
	Avg. Observed	**Avg. Computed**	**RMS error**
Below Goodwin	53.13	53.07	0.412
Knights Ferry	53.78	53.92	0.538
Orange Blossom	54.69	54.78	0.783
Oakdale Rec.	55.81	55.76	0.913
Riverbank	56.56	56.90	1.019
Ripon	58.47	58.53	1.425
confluence	60.52	61.45	1.493

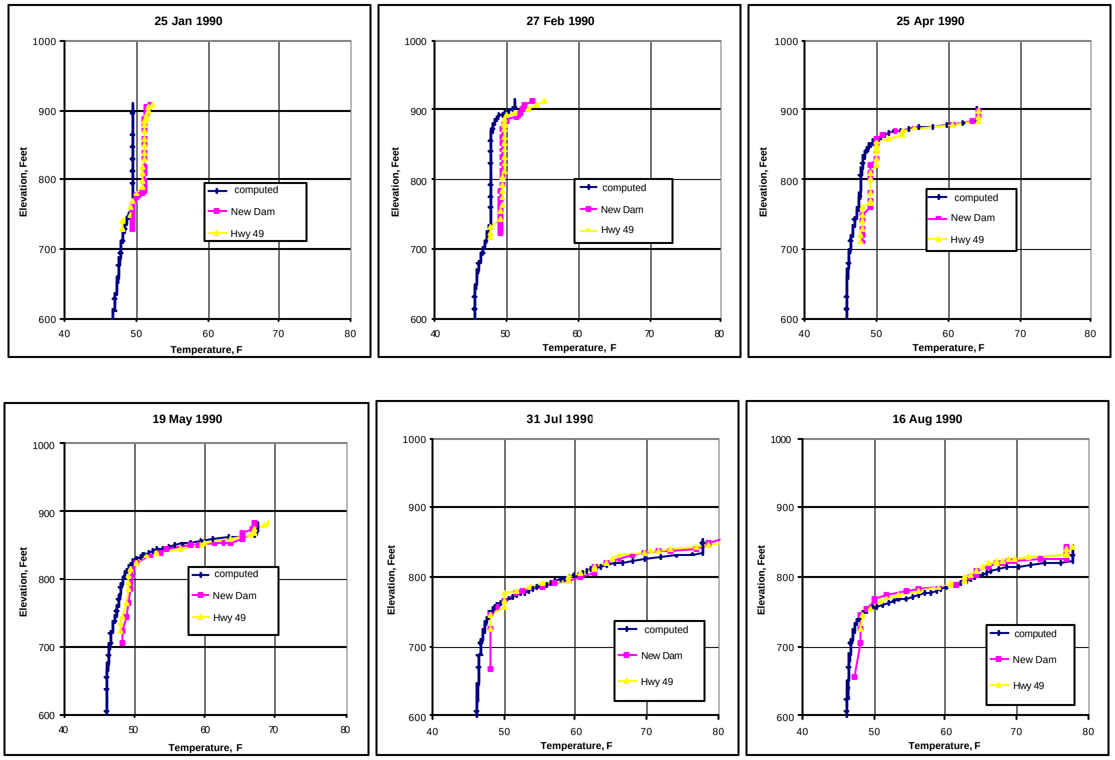
Figure 3-1 Map showing locations of water quality monitoring stations used in calibration.



Key:
Flags designate locations for thermographs
Suns designate weather stations (installed after model calibartion)

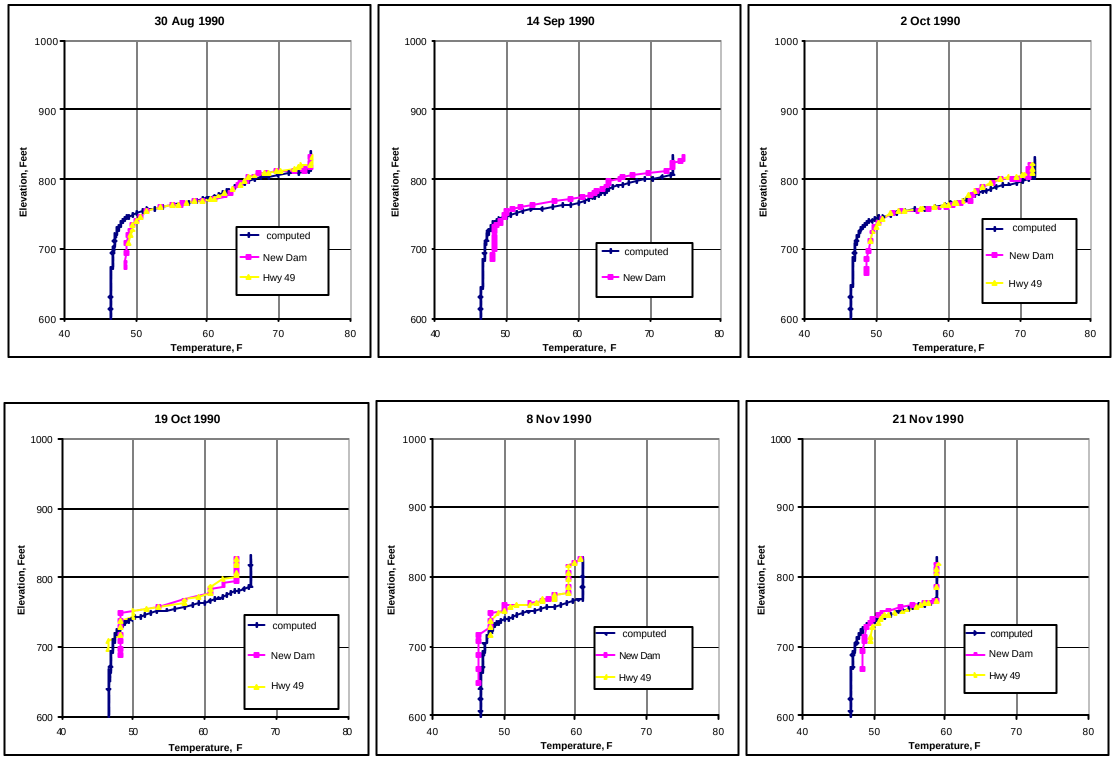
#	Site ID	Site Type	Site Name
1	COLL1	Stream	Collierville Powerhouse Tailrace
2	GMB1	Stream	Gambini Property immediately downstream of the pond at Oakdale Recreation Area
3	GOOD1	Stream	Goodwin Canyon immediately downstream of Goodwin Dam
4	GWNBTM	Stream	Goodwin Dam Log Boom (Bottom of the water column)
5	GWNMID	Stream	Goodwin Dam Log Boom (Middle of the water column)
6	GWNTOP	Stream	Goodwin Dam Log Boom (Top of the water column)
7	KF1	Stream	Knights Ferry at the Sonora Road Bridge
8	NFMF1	Stream	Below the confluence of the North and Middle Forks upstream of the Collierville Powerhouse
9	NMPH1	Stream	New Melones Powerhouse Tailrace
10	OAKR1	Stream	Oakdale Recreation Area (1/4 mile downstream of Hwy 120 Bridge)
11	OB1	Stream	1/4 mile downstream of Orange Blossom Bridge
12	OID1	Stream	Oakdale Irrigation District Canal just downstream of Goodwin Reservoir
13	RB2	Stream	Riverbank (Downstream end of Jacob Meyers Park)
14	SEWD1	Stream	Inflow to Stockton East Water District Canal at Goodwin Reservoir
15	SFRK1	Stream	South Fork of the Stanislaus approximately 2 miles upstream of New Melones
16	SPHF1	Stream	Stanislaus Powerhouse (In the Stanislaus canal immediately upstream of the forebay)
17	SS1	Stream	Approx. 1/4 mile upstream of the confluence with the San Joaquin River
18	SSJID1	Stream	Inflow to South San Joaquin Irrigation District Canal at Goodwin Reservoir
19	TULS1	Stream	Tulloch Dam Spillway
20	TULT1	Stream	Tulloch Powerhouse Tailrace
21	STTR1	Stream	Stanislaus River above Two Rivers (approx. 100 meters above the confluence)

Figure 3-2 Computed and observed vertical temperature profiles in New Melones Reservoir for January 1990 – August 1990.



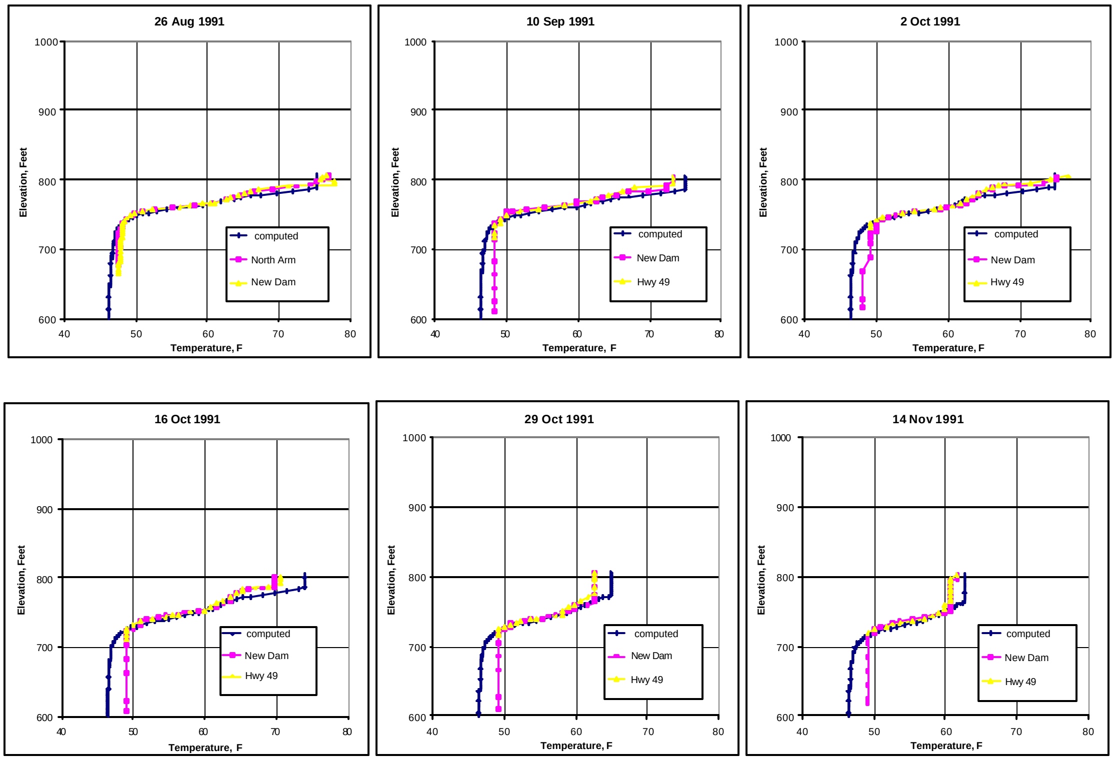
3.6

Figure 3-3 Computed and observed vertical temperature profiles in New Melones Reservoir for August 1990 – November 1990.



3.7

Figure 3-4 Computed and observed vertical temperature profiles in New Melones Reservoir for August 1991 – November 1991.



3.8

Figure 3-5 Computed and observed vertical temperature profiles in New Melones Reservoir for November 1991 – July 1993.

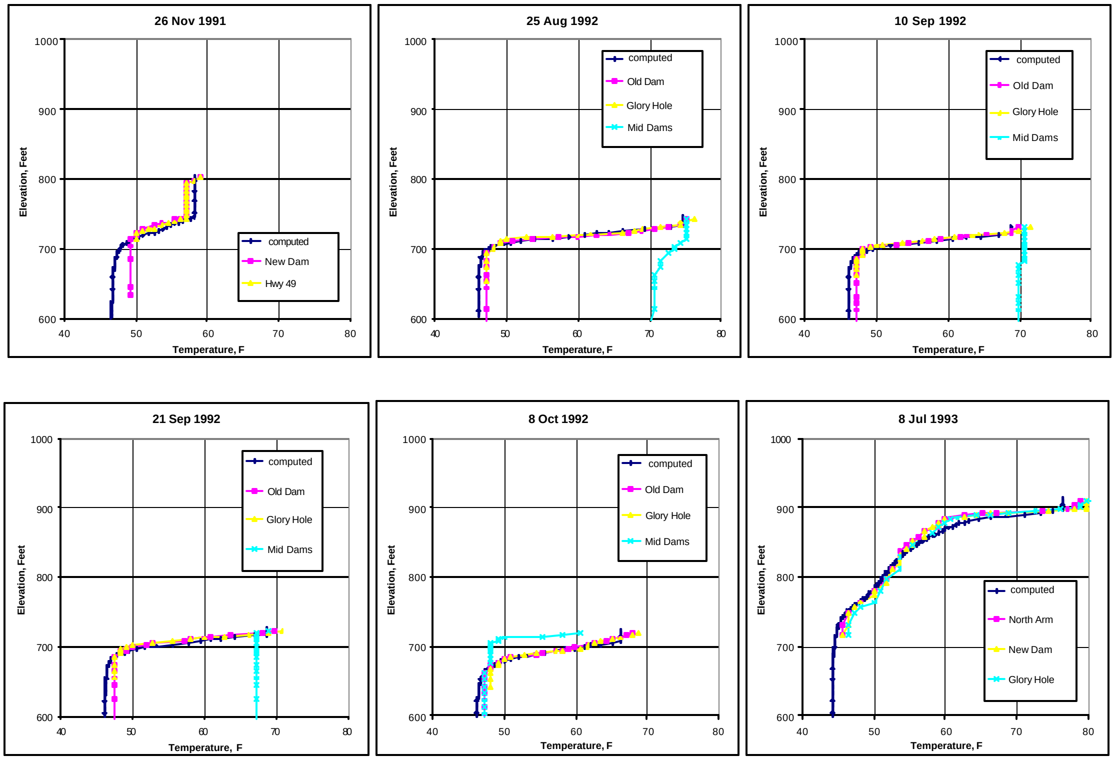
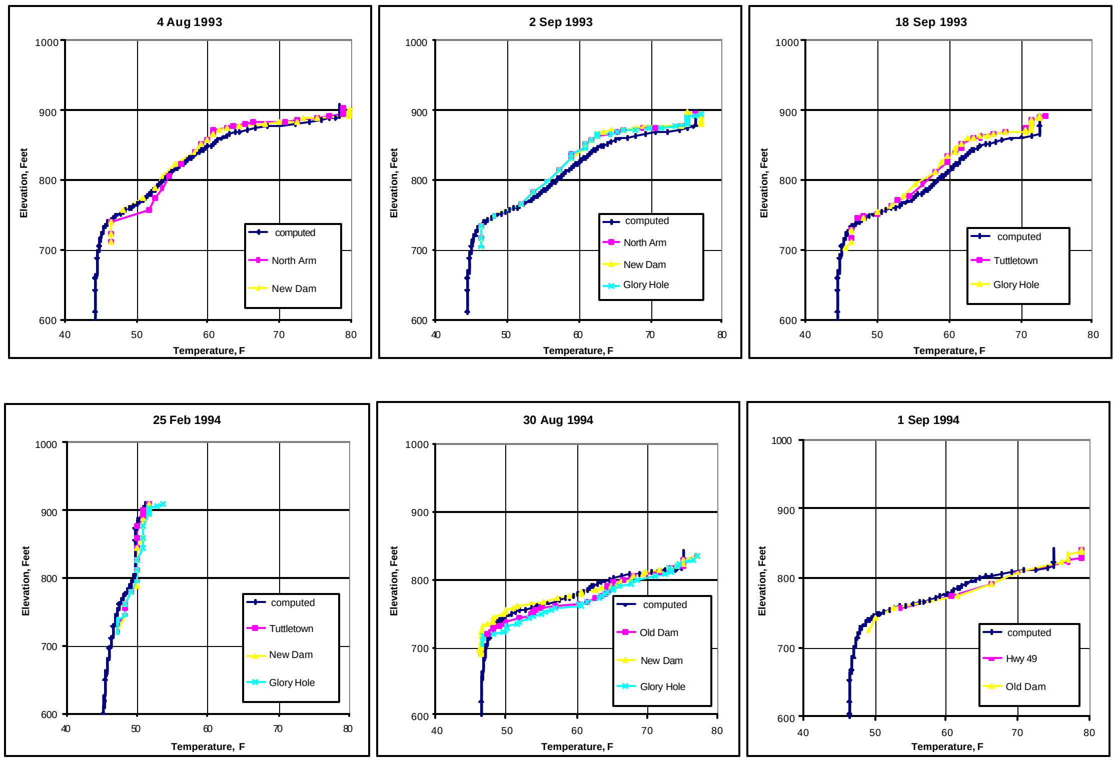


Figure 3-6 Computed and observed vertical temperature profiles in New Melones Reservoir for August 1993 – September 1994.



3.10

Figure 3-7 Computed and observed vertical temperature profiles in New Melones Reservoir for September 1994 – February 1999.

3.11

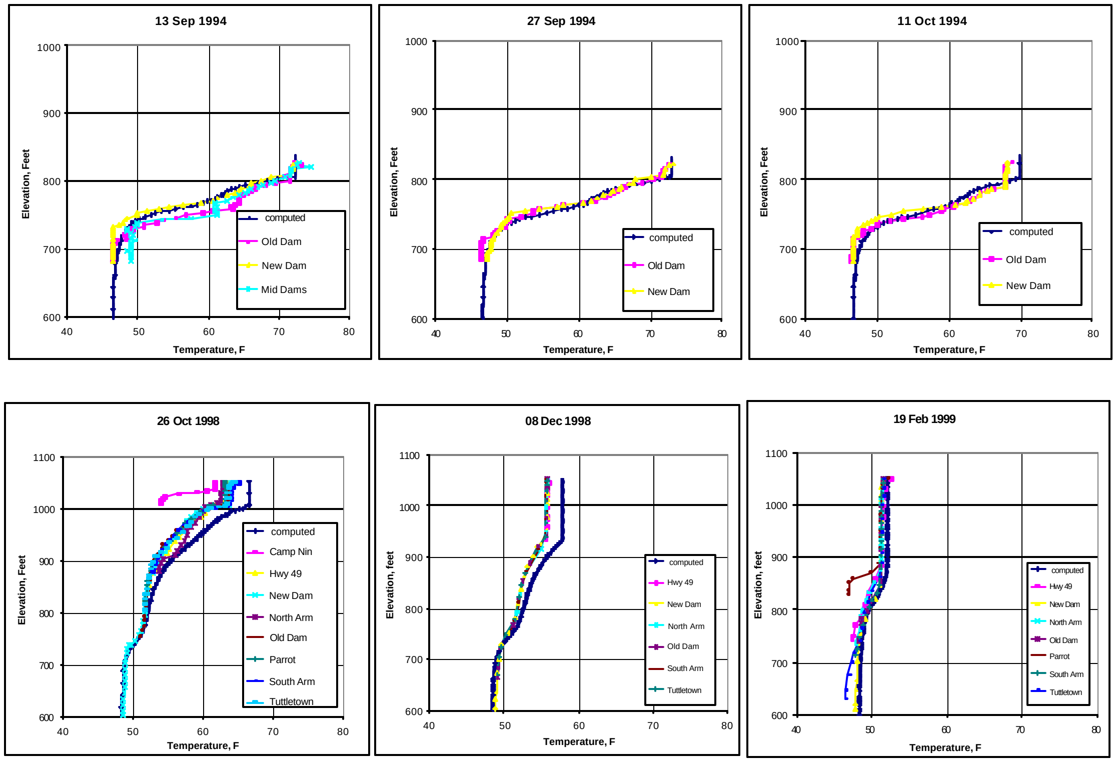
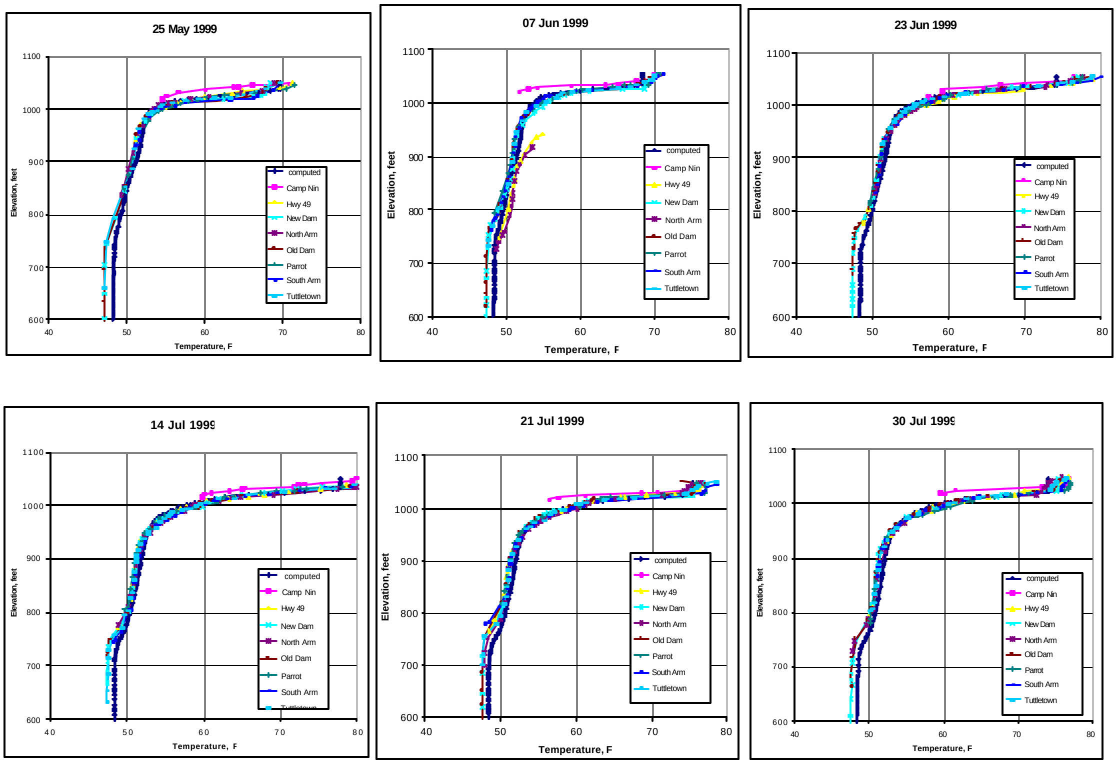


Figure 3-8 Computed and observed vertical temperature profiles in New Melones Reservoir for May 1999 – July 1999.



3.12

Figure 3-9 Computed and observed vertical temperature profiles in New Melones Reservoir for August 1999 – September 1999.

3.13

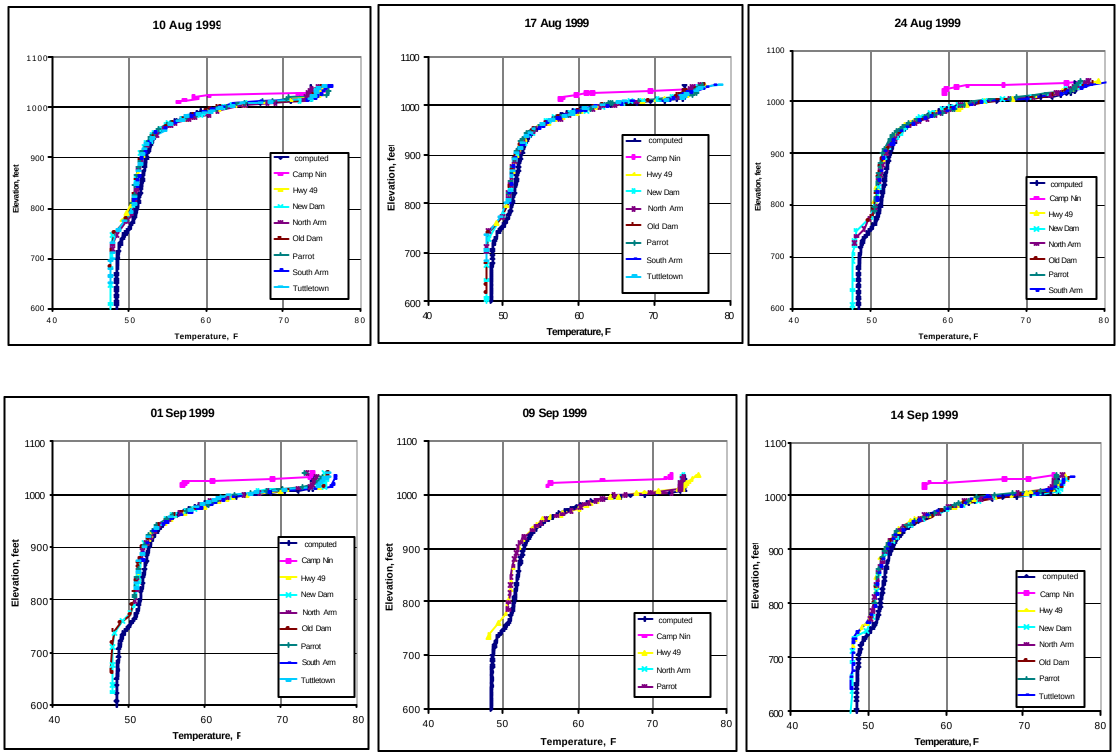
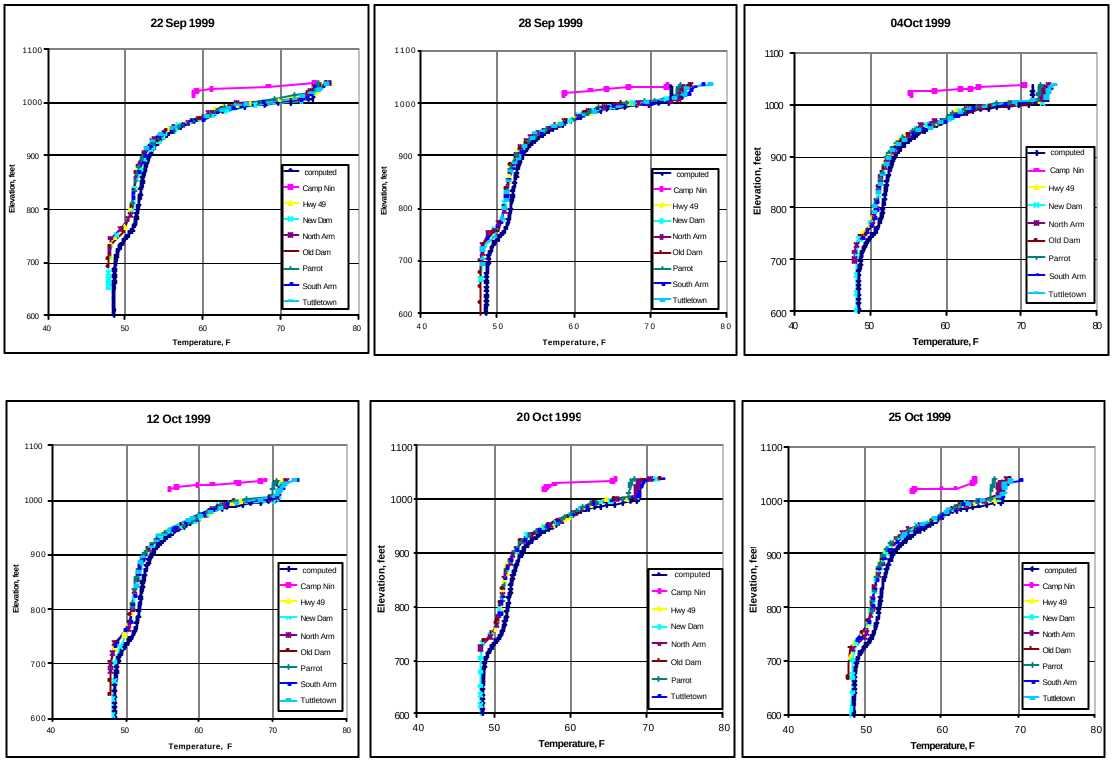
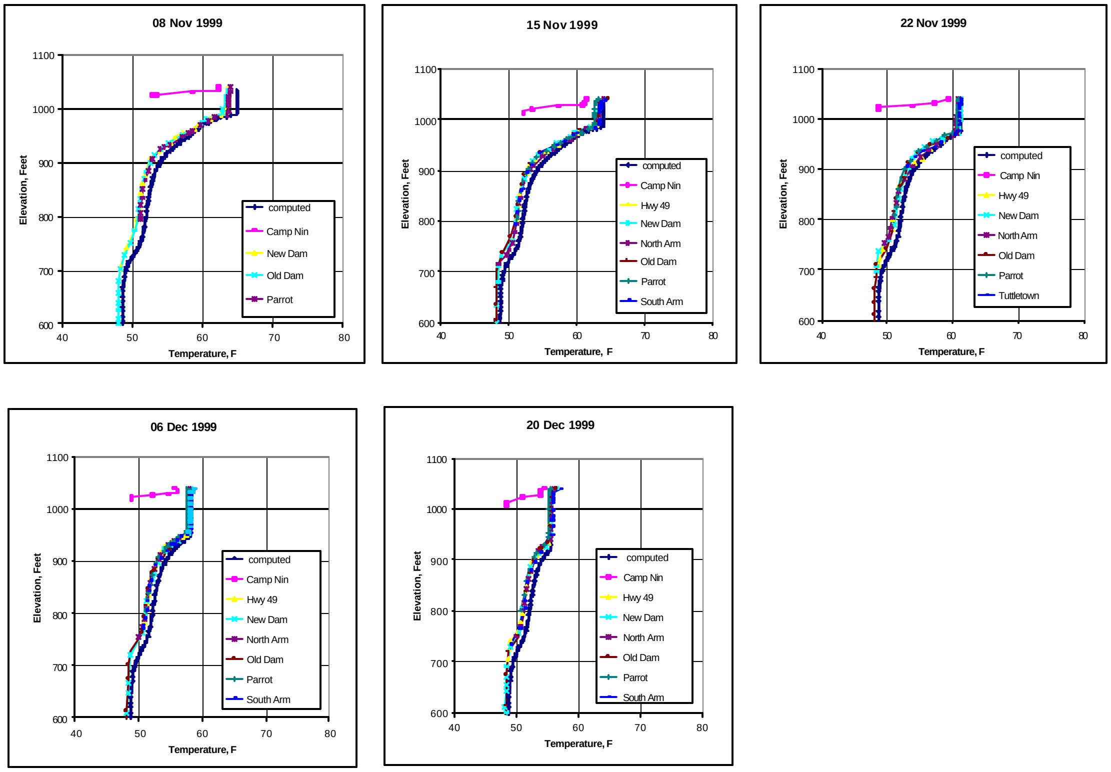


Figure 3-10 Computed and observed vertical temperature profiles in New Melones Reservoir for September 1999 – October 1999.



3.14

Figure 3-11 Computed and observed vertical temperature profiles in New Melones Reservoir for November 1999 – December 1999



3.15

Figure 3-12 Computed and observed vertical temperature profiles in Tulloch Reservoir for August 1990 – October 1991

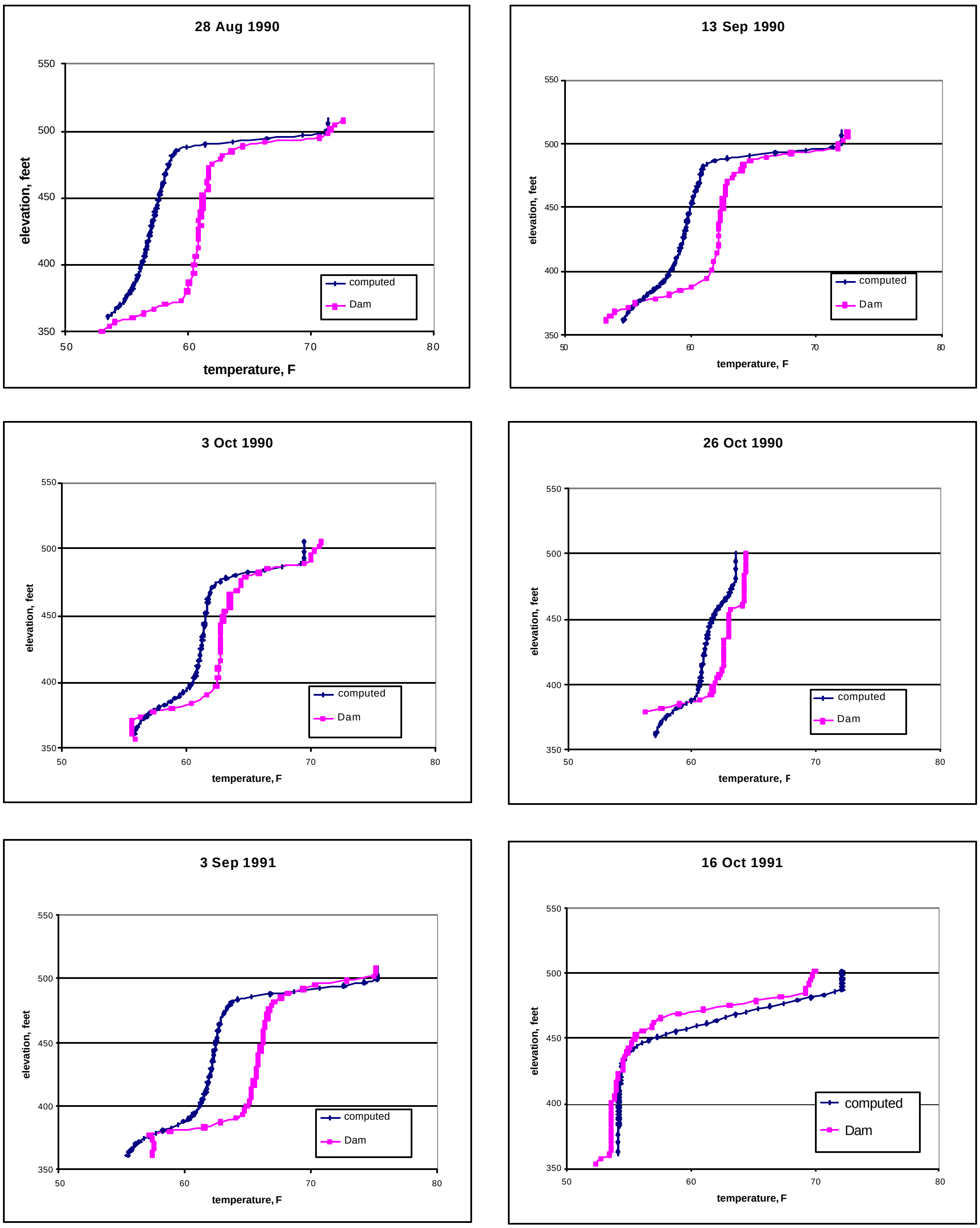


Figure 3-13 Computed and observed vertical temperature profiles in Tulloch Reservoir for December 1991 – September 1993.

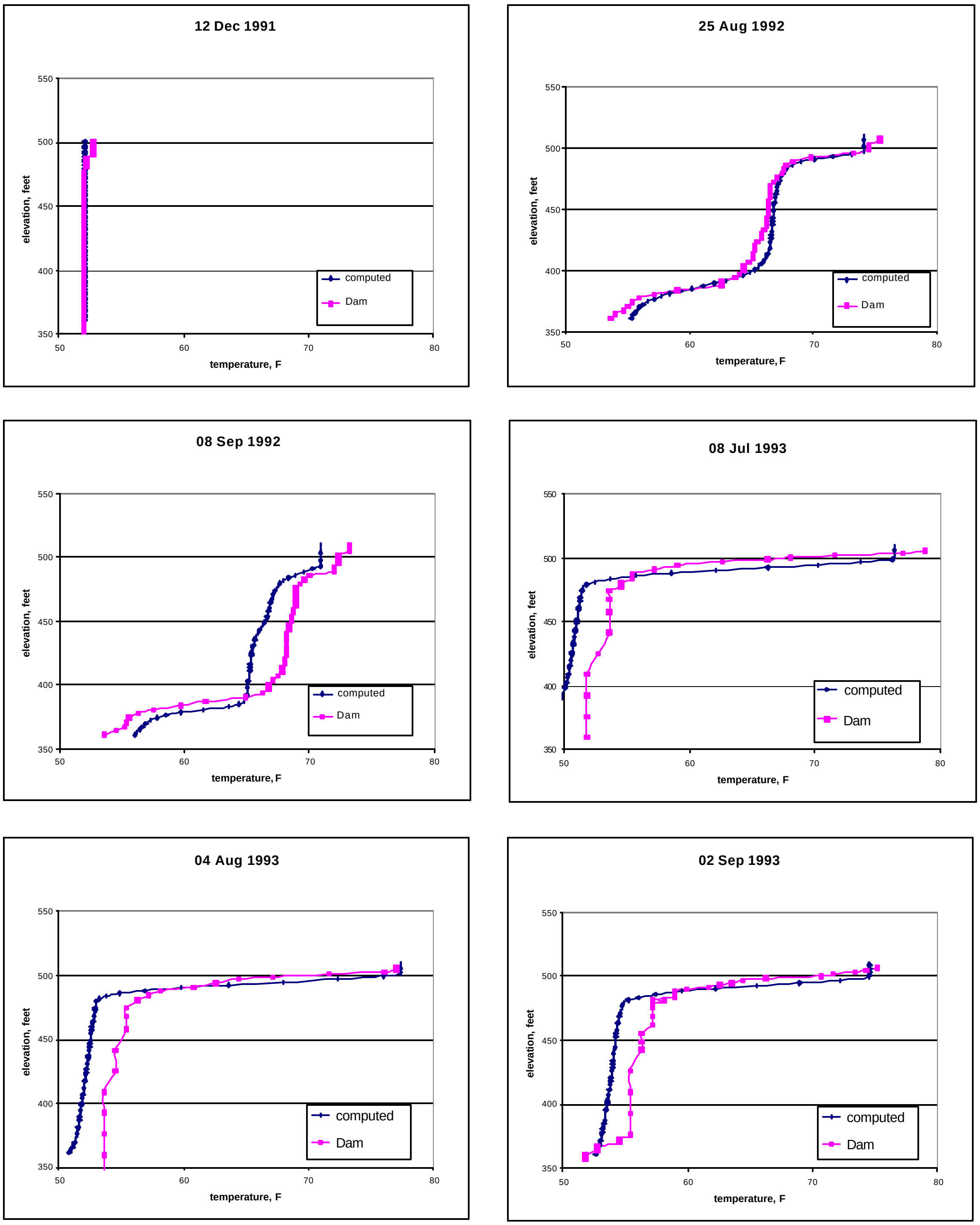


Figure 3-14 Computed and observed vertical temperature profiles in Tulloch Reservoir for September 1993 – October 1998.

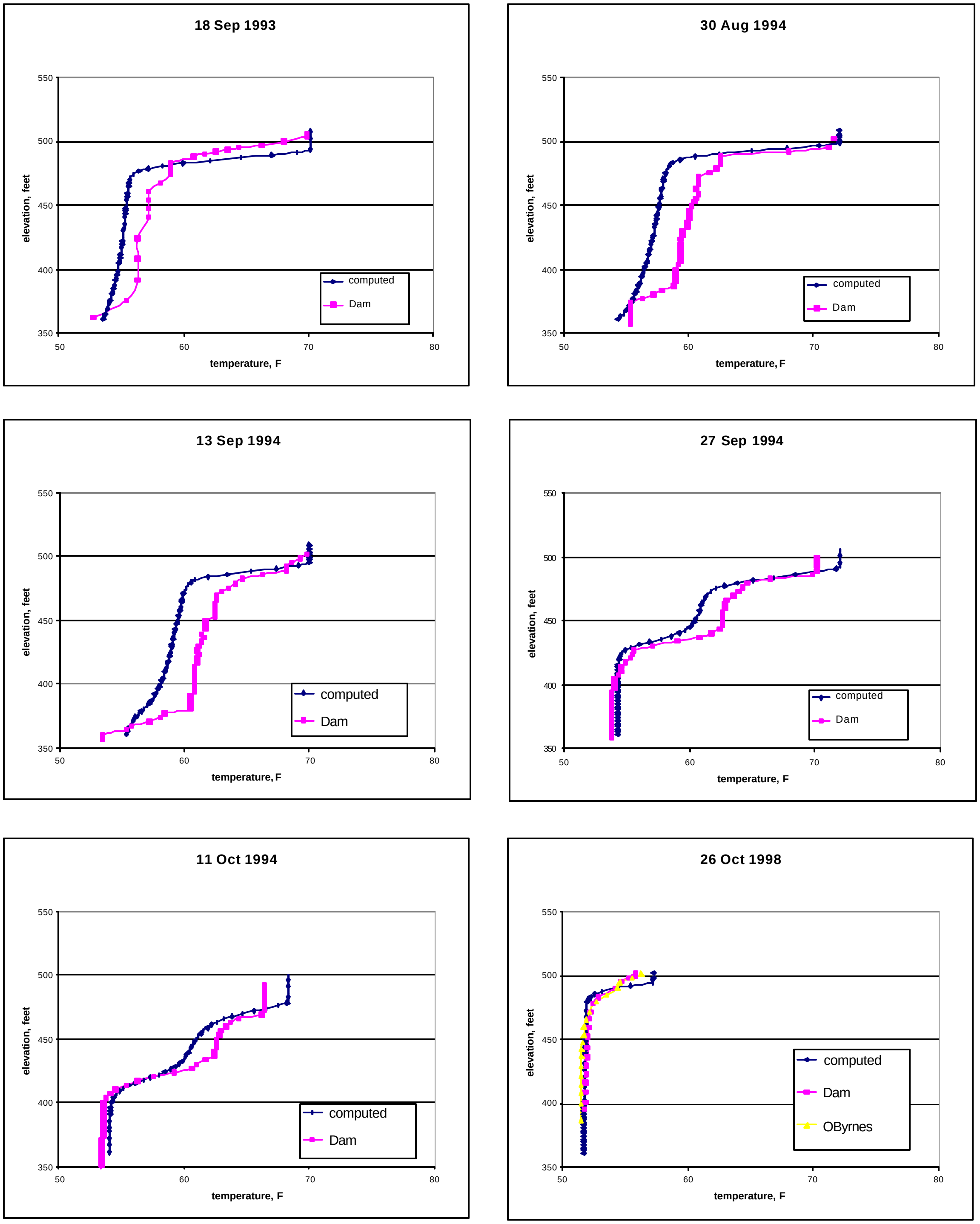


Figure 3-15 Computed and observed vertical temperature profiles in Tulloch Reservoir for December 1998 – July 1999.

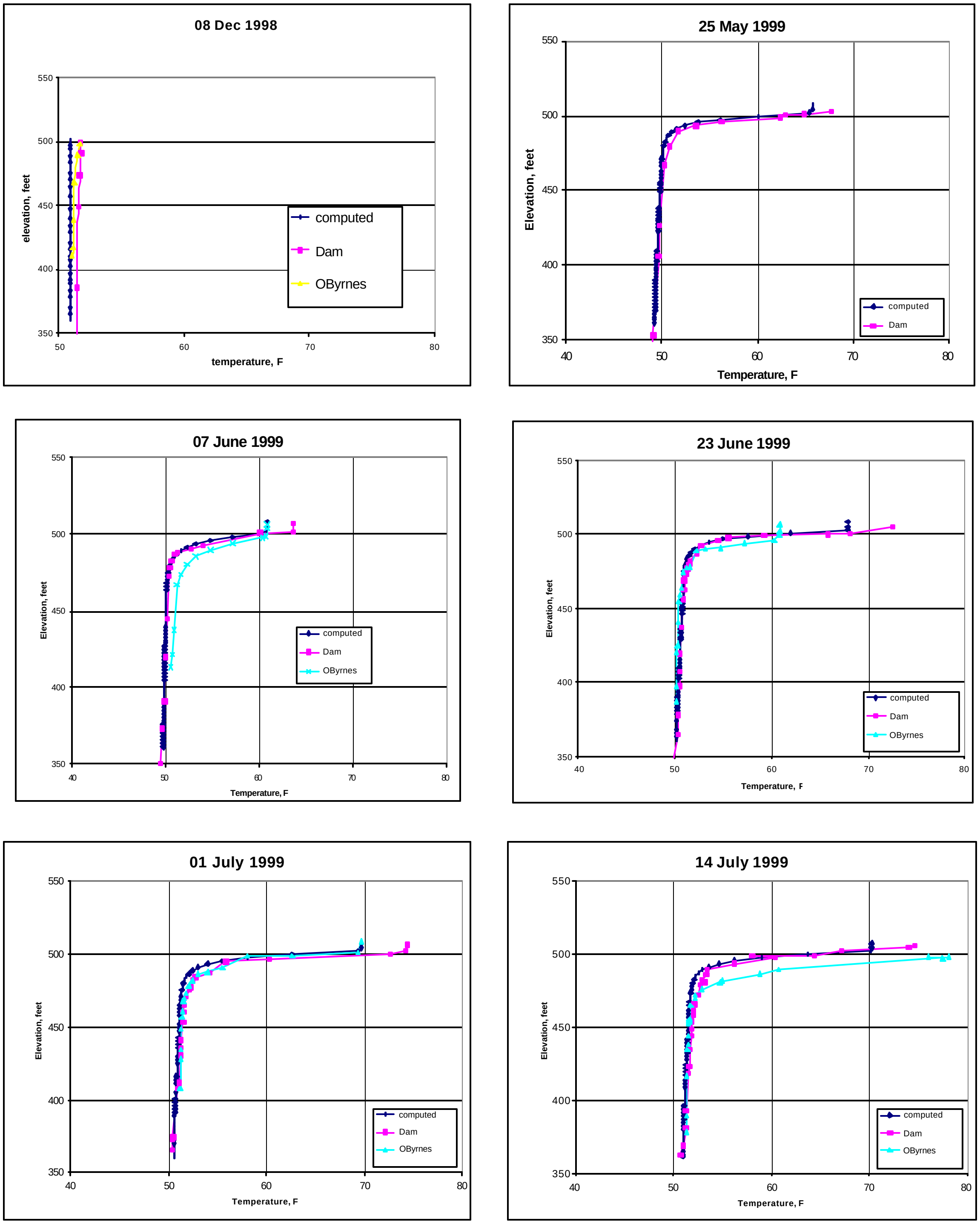


Figure 3-16 Computed and observed vertical temperature profiles in Tulloch Reservoir for July 1999 – September 1999.

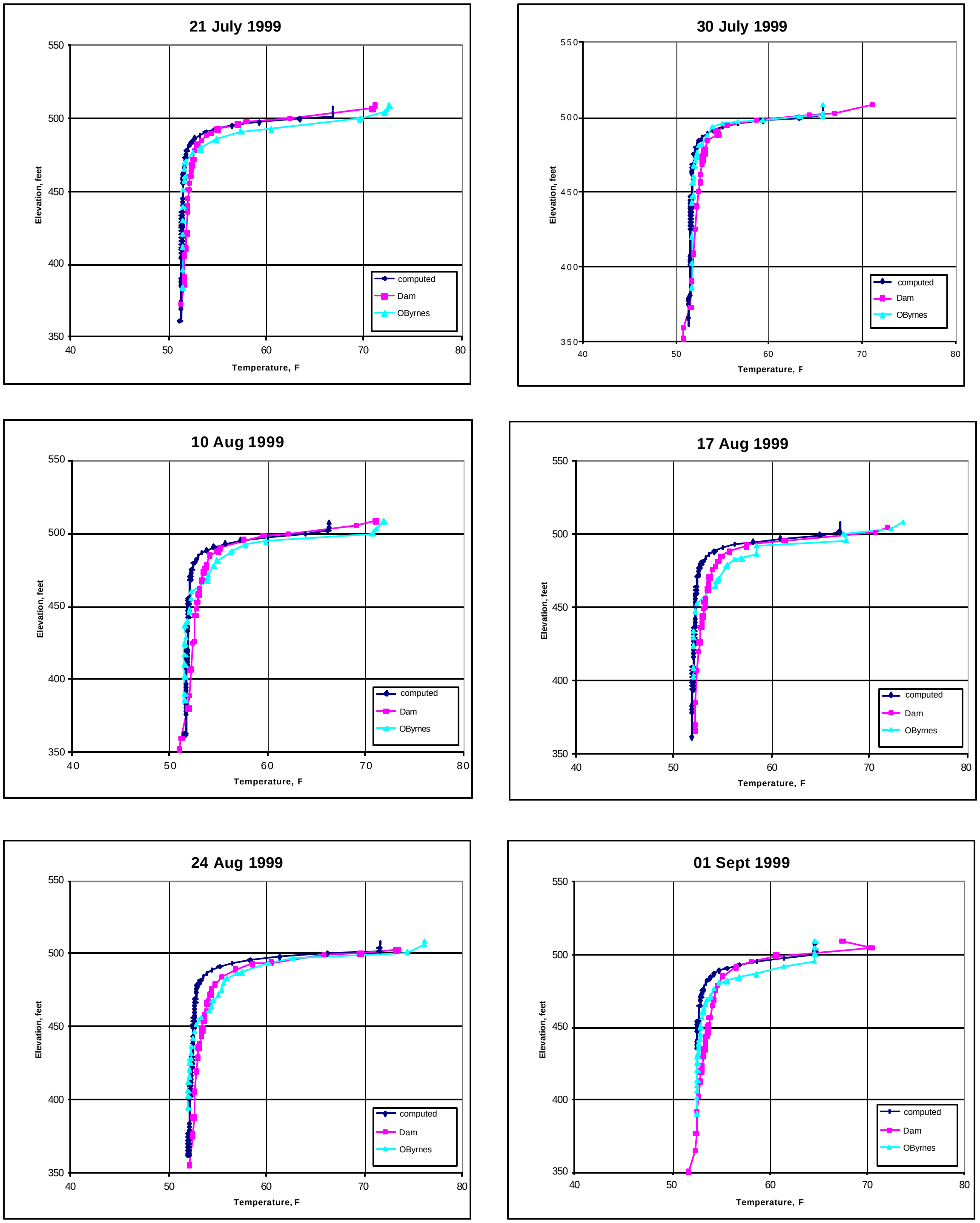


Figure 3-17 Computed and observed vertical temperature profiles in Tulloch Reservoir for September 1999 – October 1999.

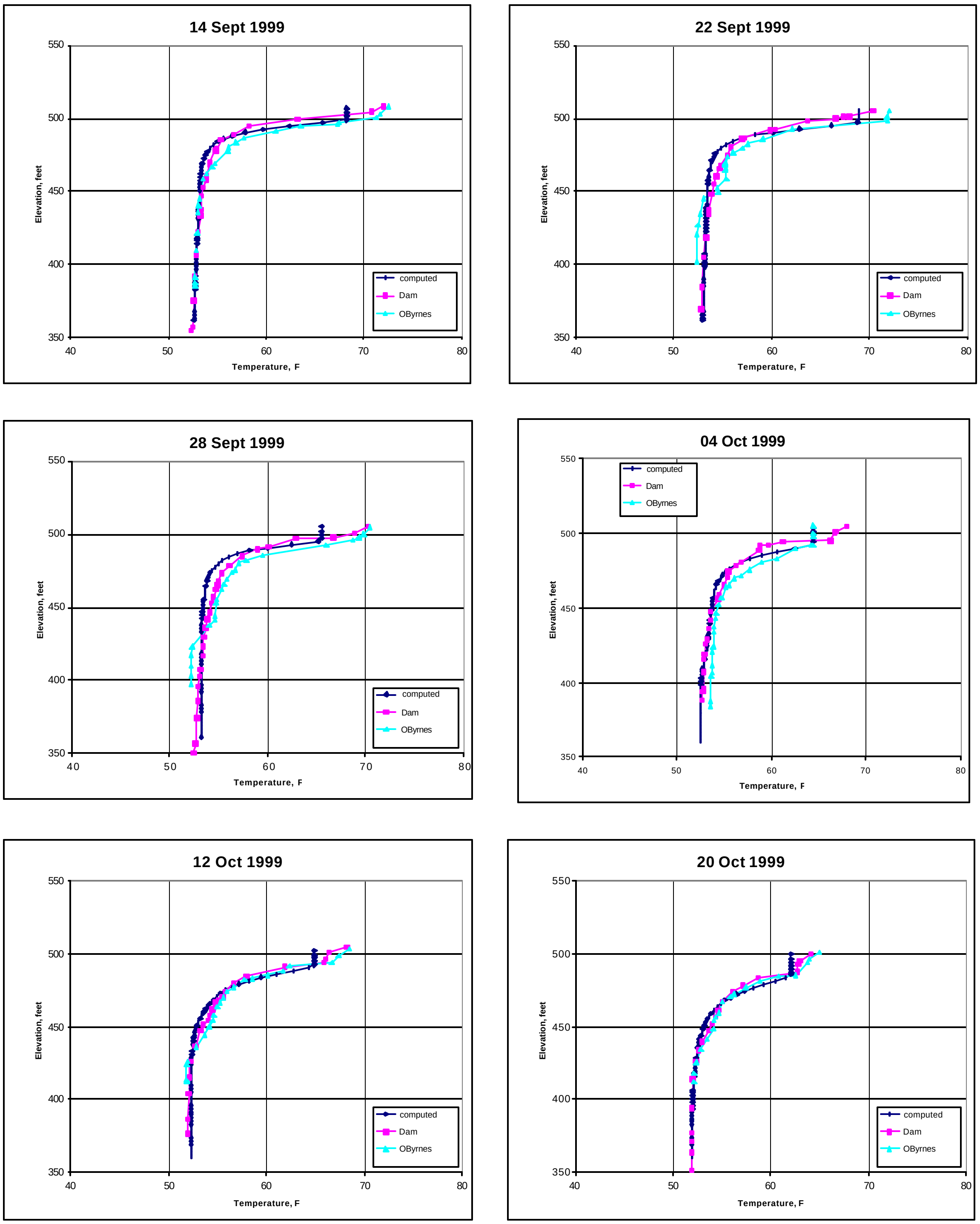


Figure 3-18 Computed and observed vertical temperature profiles in Tulloch Reservoir for November 1999 – December 1999.

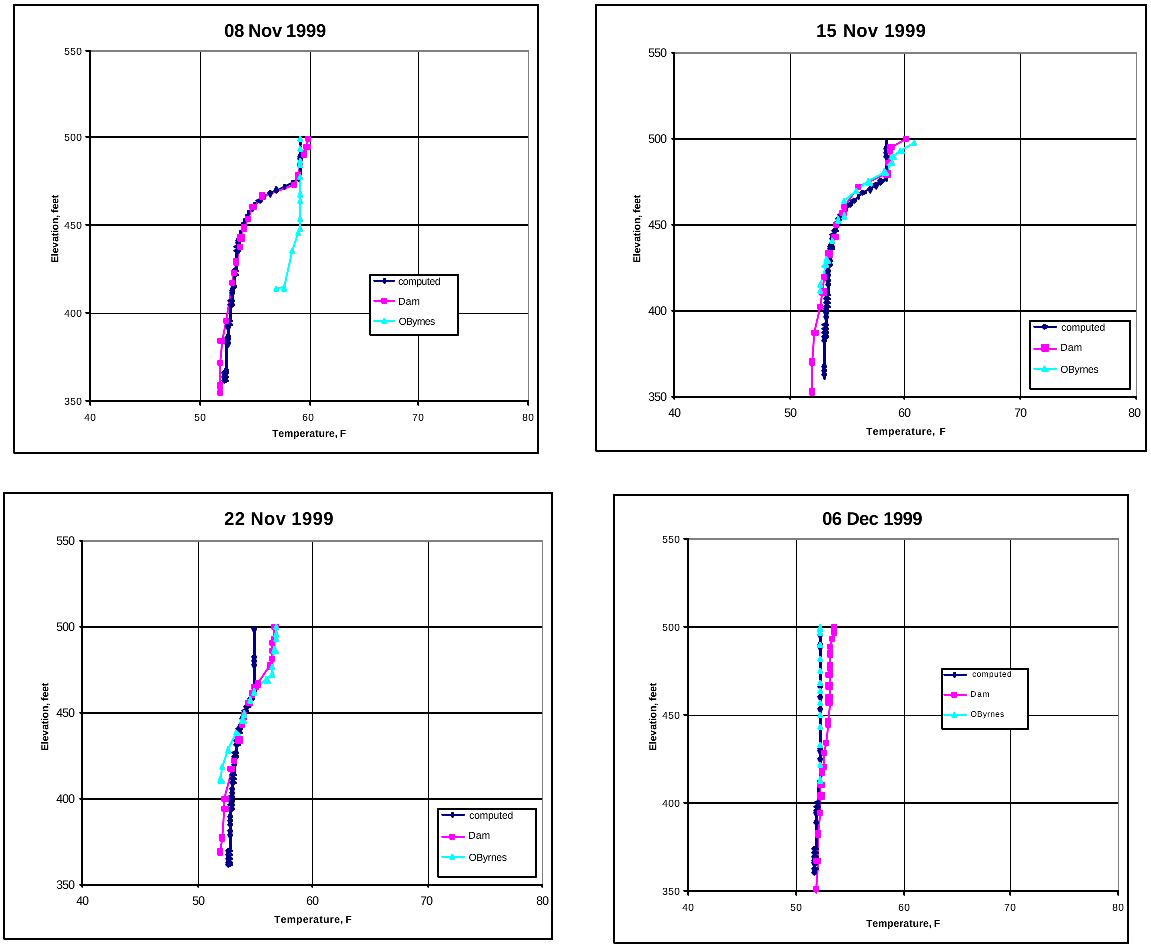


Figure 3-19 Maximum, average, and minimum temperature time series below Goodwin Dam during 1990 – 1993.

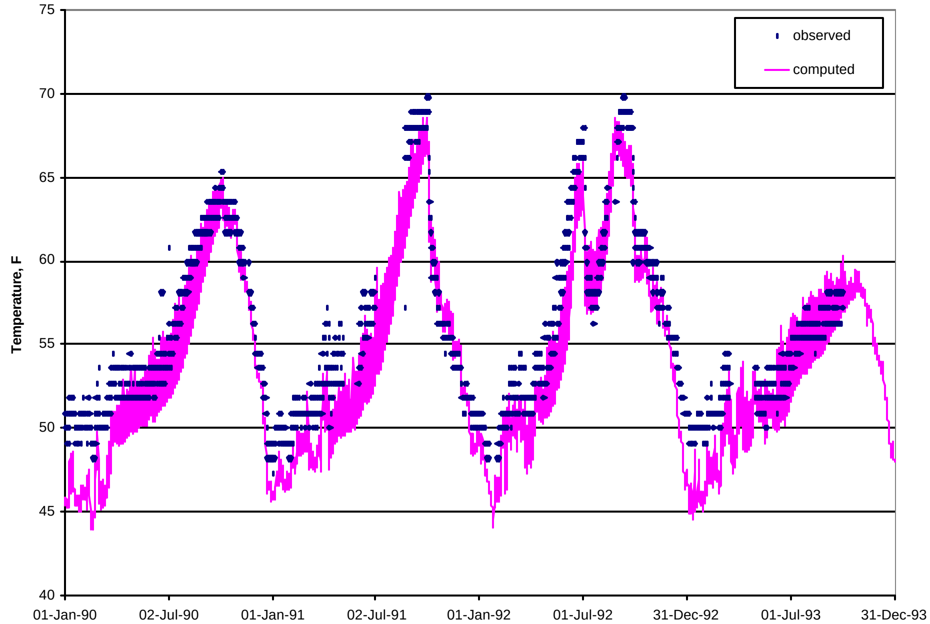


Figure 3-20 Computed versus observed temperatures below Goodwin Dam during 1990 – 1993.

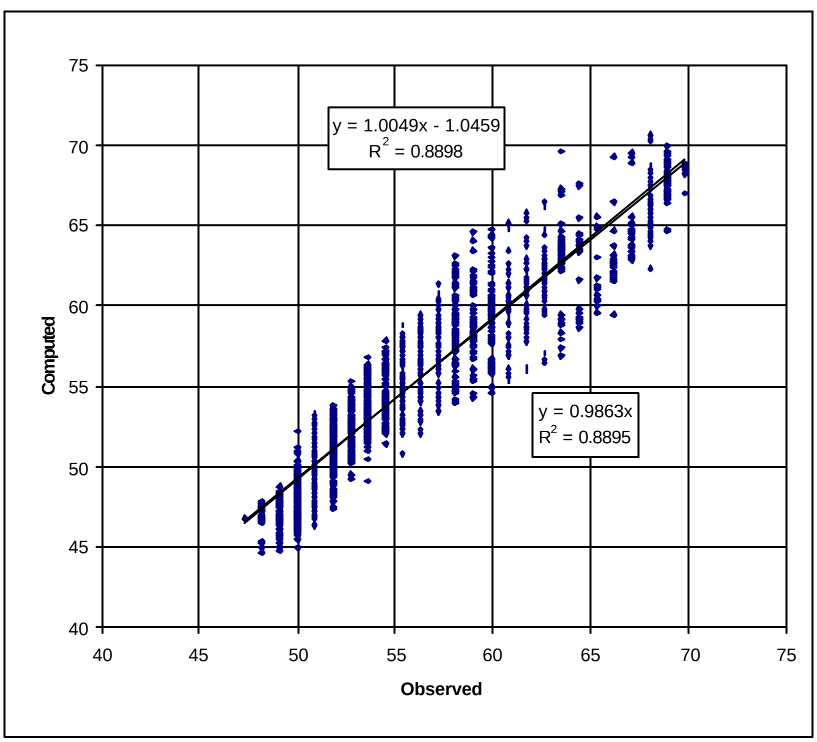


Figure 3-21 Maximum, average, and minimum temperature time series below Goodwin Dam during 1999.

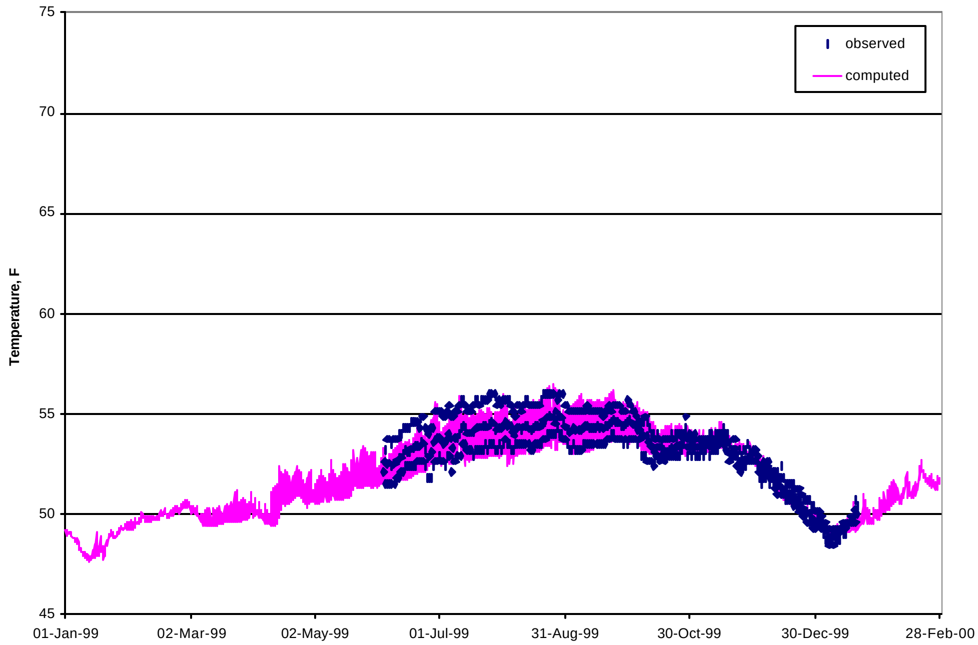


Figure 3-22 Computed versus observed temperatures below Goodwin Dam during 1999.

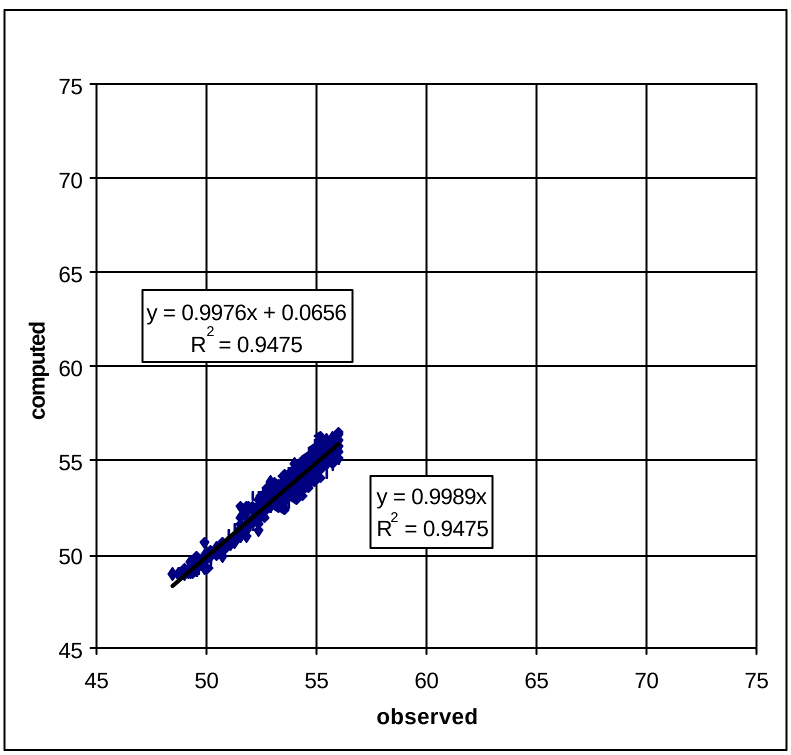


Figure 3-23 Maximum, average, and minimum temperature time series below Knights Ferry during 1999.

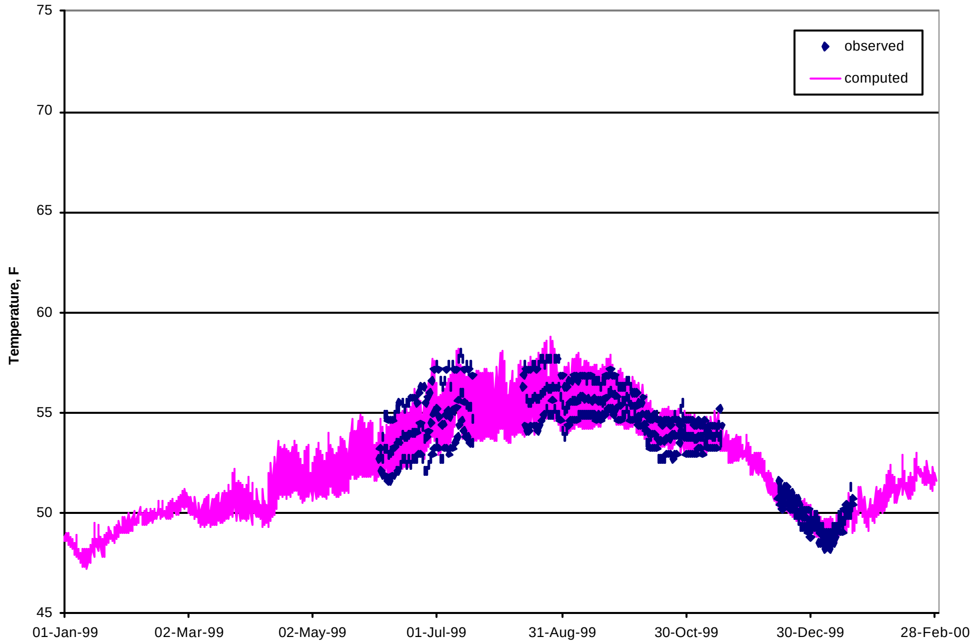


Figure 3-24 Computed versus observed temperatures at Knights Ferry during 1999.

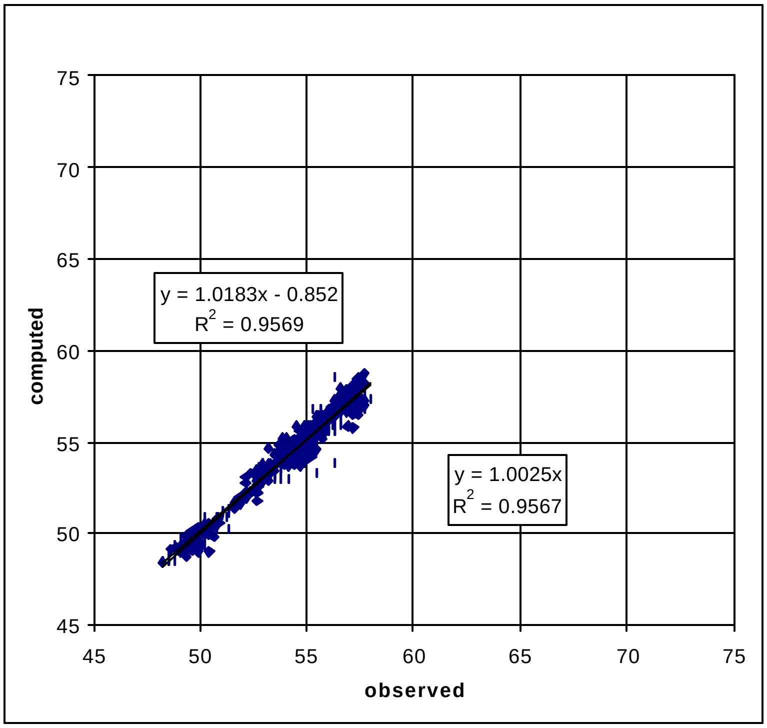


Figure 3-25 Maximum, average, and minimum temperature time series at Orange Blossom during 1999.

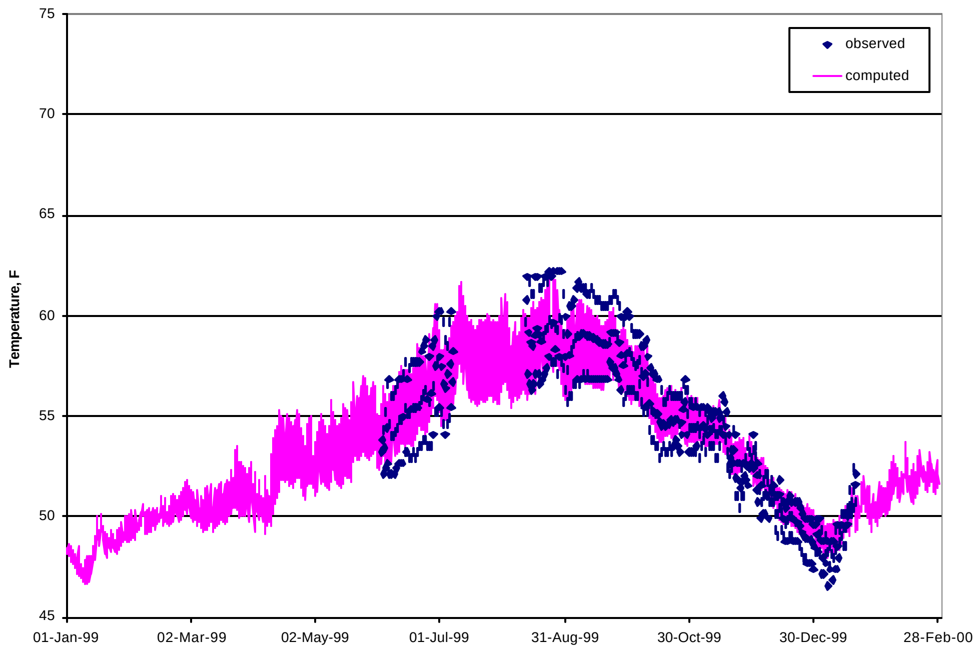


Figure 3-26 Computed versus observed temperatures at Orange Blossom during 1999.

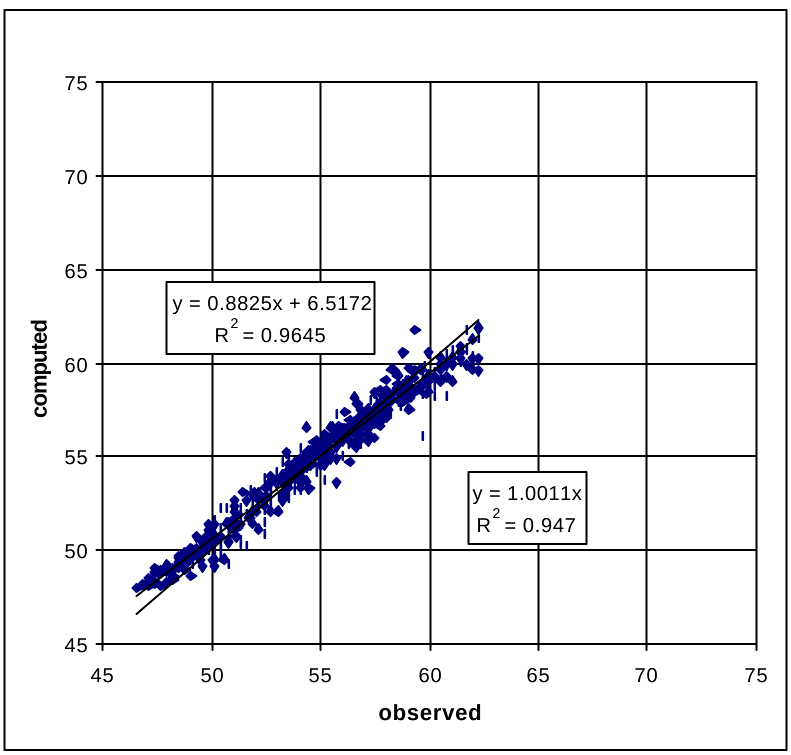


Figure 3-27 Maximum, average, and minimum temperature time series at Oakdale Recreation during 1999.

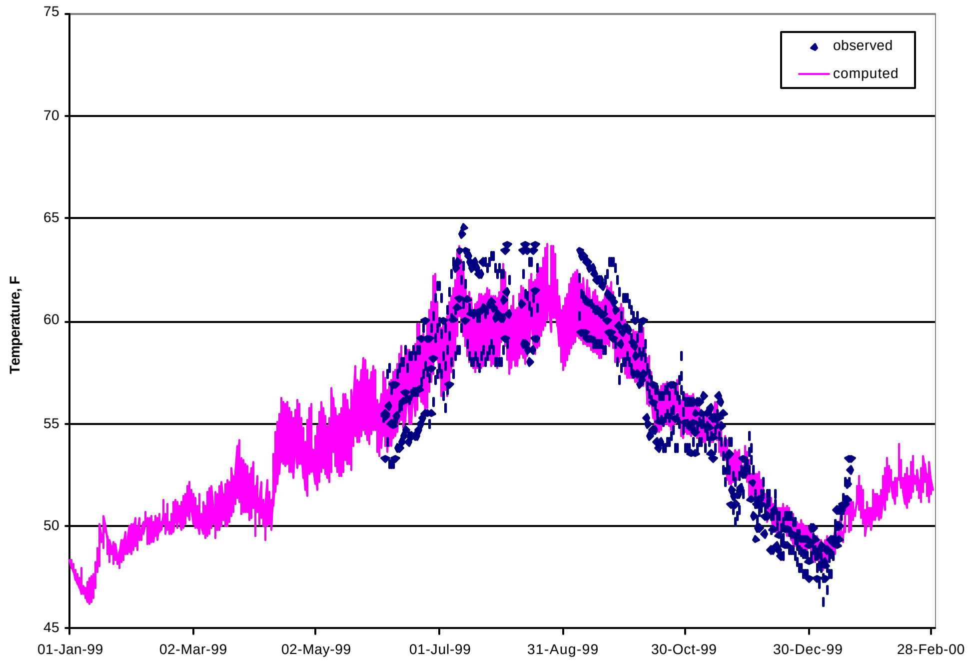


Figure 3-28 Computed versus observed temperatures at Oakdale Recreation during 1999.

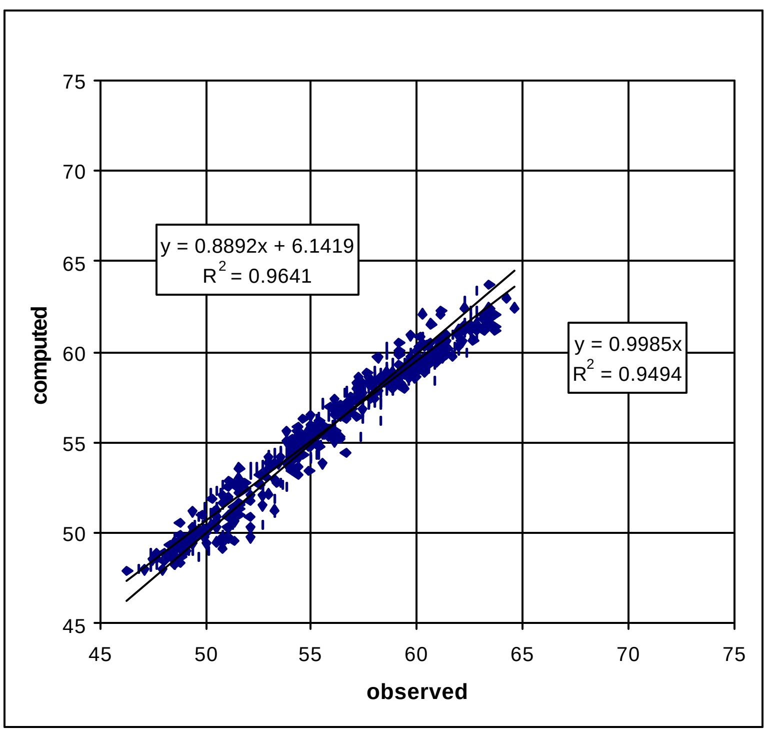


Figure 3-29 Maximum, average, and minimum temperature time series at Riverbank during 1999.

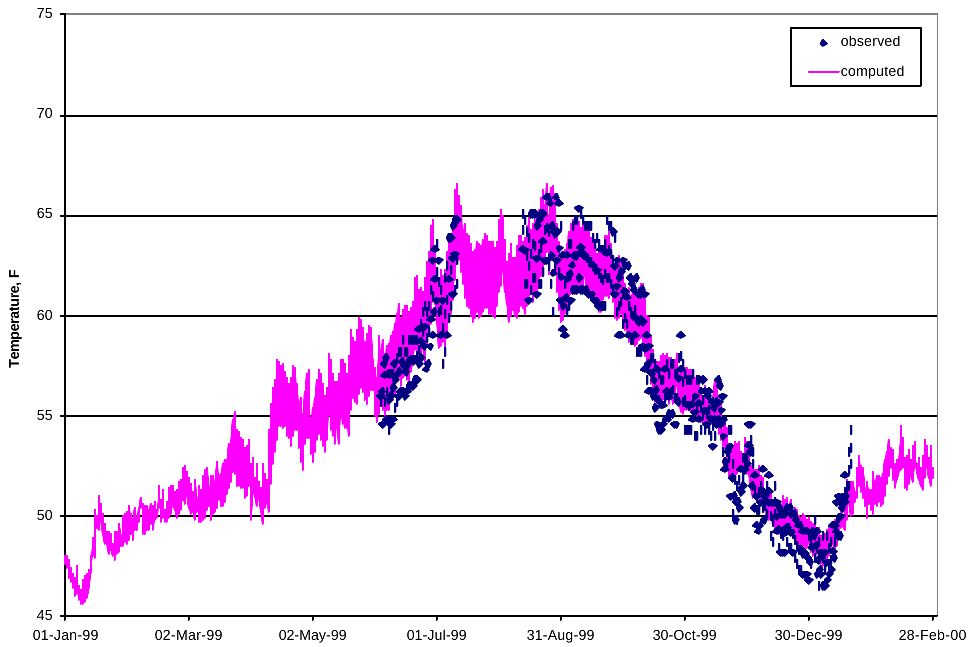


Figure 3-30 Computed versus observed temperatures at Riverbank during 1999.

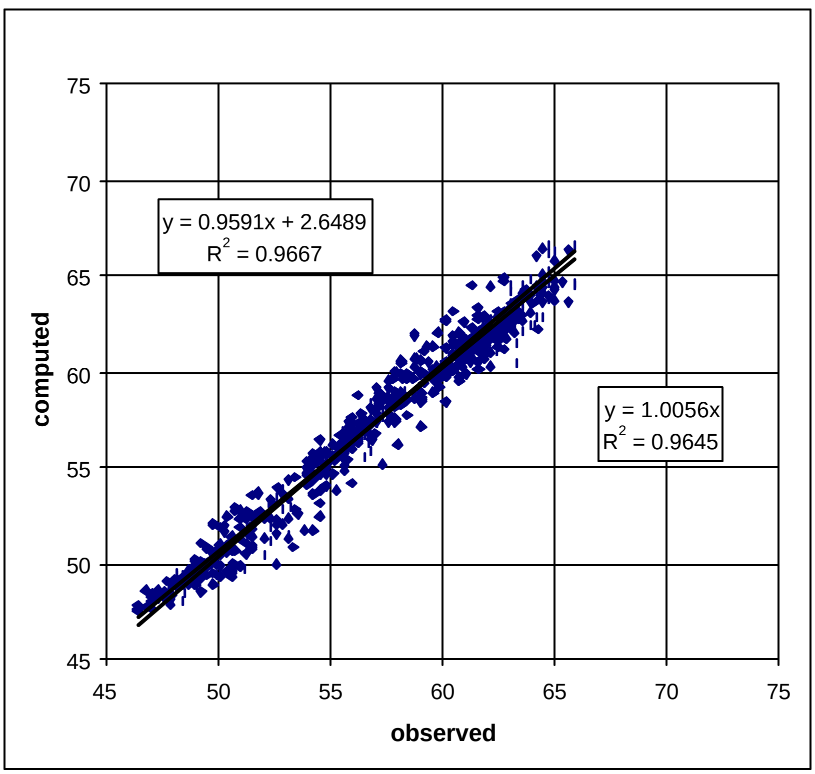


Figure 3-31 Maximum, average, and minimum temperature time series at Ripon during June 1993 – December 1998.

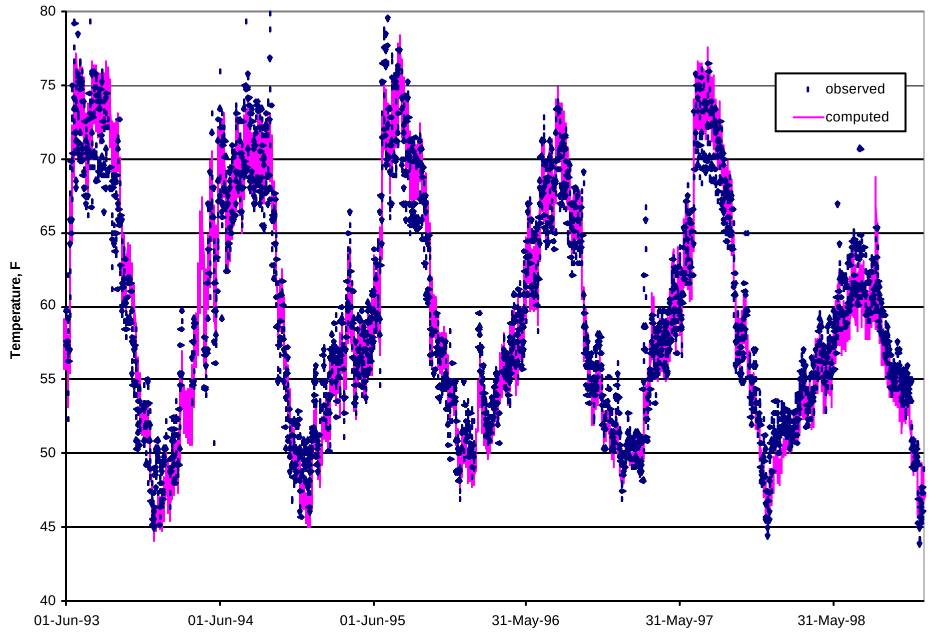


Figure 3-32 Computed versus observed temperatures at Ripon during June 1993 – December 1998.

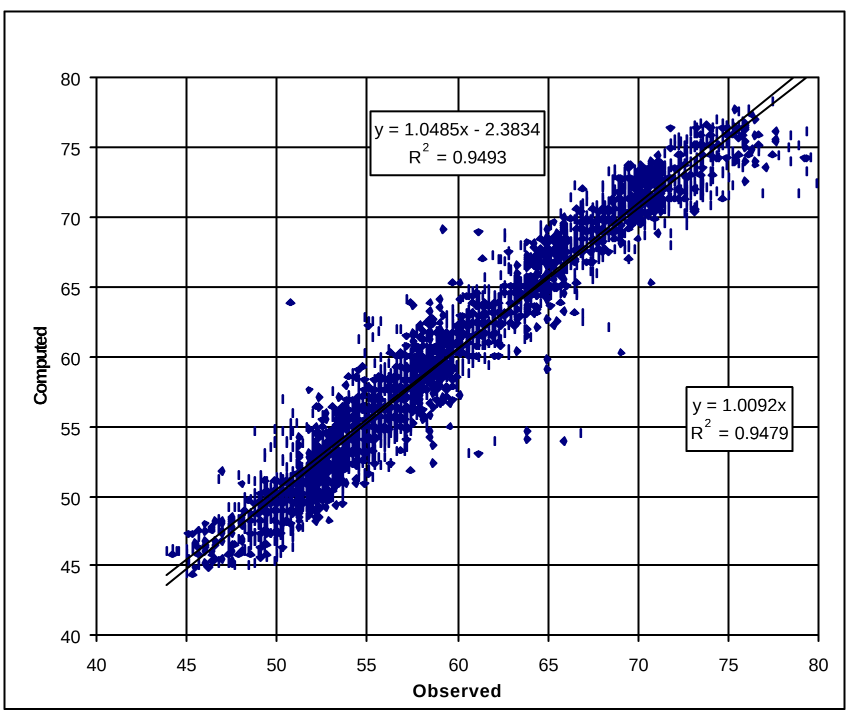


Figure 3-33 Maximum, average, and minimum temperature time series at Ripon during 1999.

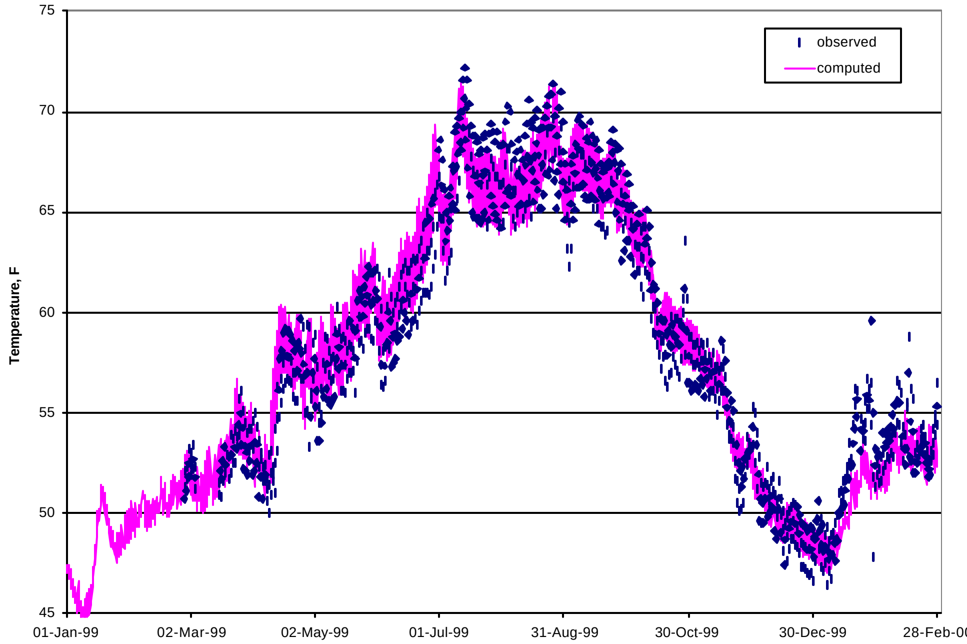


Figure 3-34 Computed versus observed temperatures at Ripon during 1999.

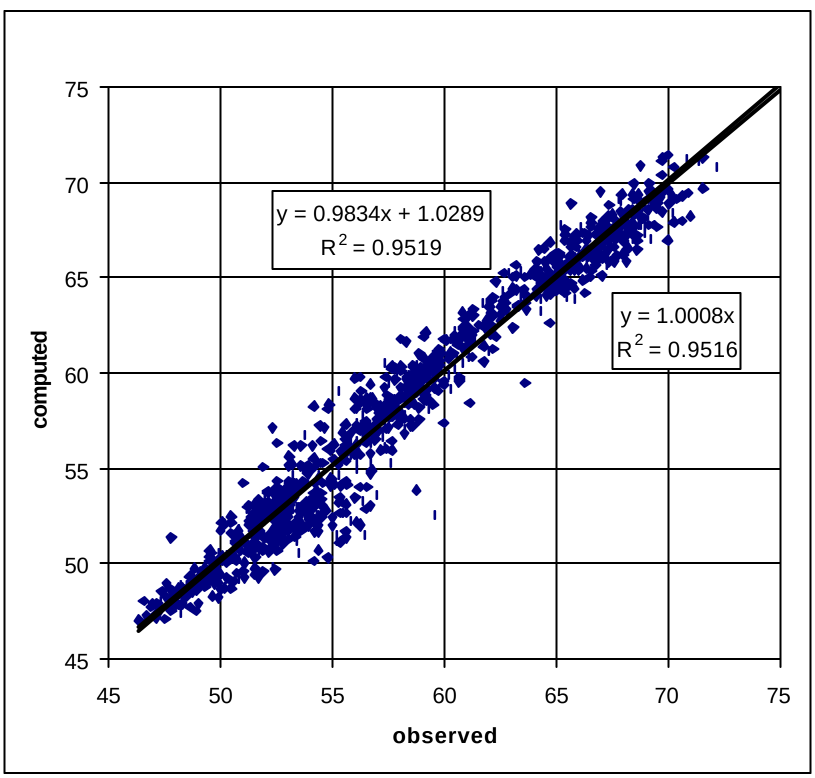


Figure 3-35 Maximum, average, and minimum temperature time series at the Stanislaus-San Joaquin confluence during 1999.

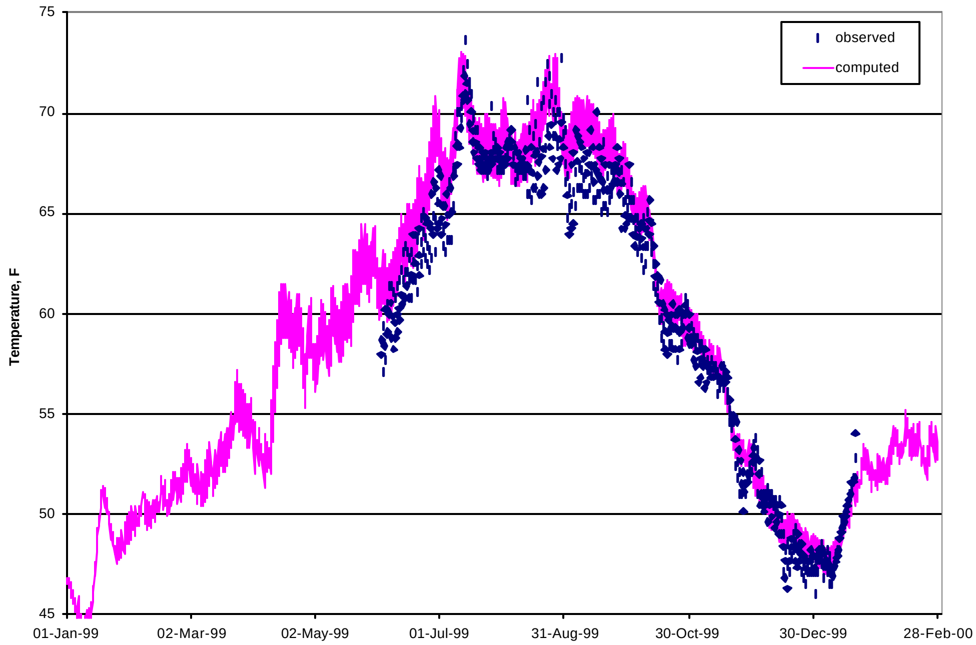
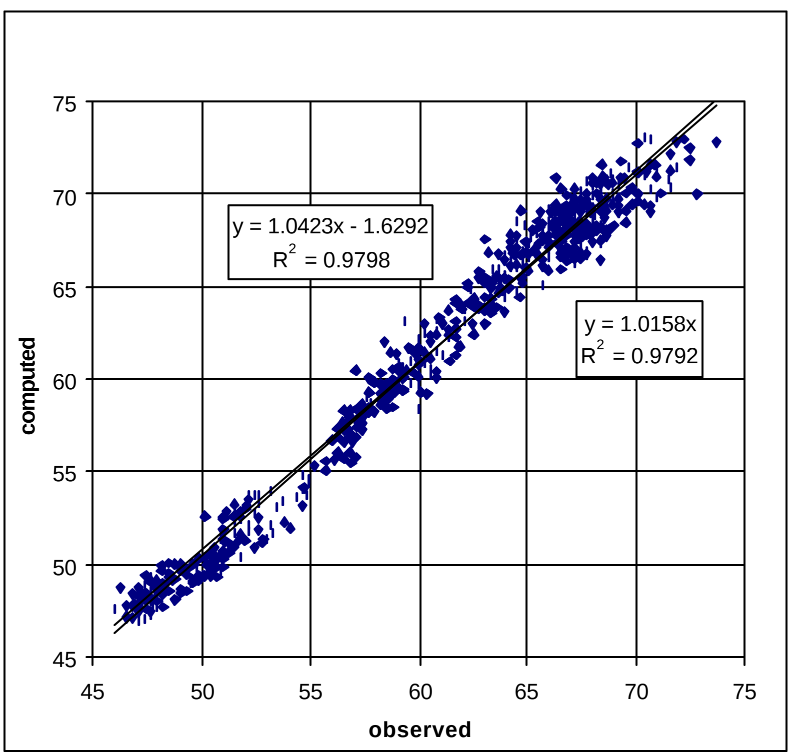


Figure 3-36 Computed versus observed temperatures at the Stanislaus-San Joaquin confluence during 1999.



4 OPERATIONS STUDY

4.1 GENERAL

The purpose of the Operations Study was to investigate various mechanisms for water temperature improvements in the Stanislaus River both through operational and/or structural measures at New Melones Reservoir, Tulloch Reservoir and Goodwin Pool.

The model simulated eleven different cases of Stanislaus River operation. For each case the model estimated the magnitude and duration of water temperature conditions at critical points on the river, and the effect on water supply and storage at New Melones Reservoir. The driving force behind the different cases is the desire to meet water temperature objectives at critical points in the river system that would enhance habitat conditions for fall-run Chinook salmon and Steelhead rainbow trout. The temperature objectives were developed by the California Department of Fish and Game which identified three zones of water temperature conditions: Optimal, sub-lethal and critical. The range of temperatures for each zone varies with time, location and fish type. Given the mechanism available under each case, the model attempted to elevate water temperatures in the river above the threshold of the critical zone.

The results for the eleven cases are presented in graphical and tabular forms showing the ranking of the cases in accordance with their level of success in achieving temperature objectives.

4.2 HYDROLOGIC INPUT DATA

The input data consisted of two hydrologic data sets:

1) Historical conditions for the period 1983 to 1996

2) Simulated conditions for the period 1983 to 1996

The period 1983 to 1996 was selected because it represents the most recent storage cycle in New Melones where the reservoir reached a full capacity, reduced to almost dead storage and then recovered, as illustrated in Figure 4-1.

Other assumptions related to these data sets are described herein:

1) Historical Conditions:

The historical conditions were based on daily inflow to New Melones, Tulloch and Goodwin Pool, tributaries inflow, accretions, reservoirs evaporations, reservoirs releases and return flow. Releases were accounted separately for powerplant flow, low-level outlet flow and dams spill. The data was obtained from the Central Valley Operation (CVO) database of the USBR, California Data Exchange Center (CDEC) and the U.S. Geological Survey (USGS) gage stations at Knights Ferry, Oakdale and Ripon.

2) Simulated Conditions:

The simulated conditions were based on monthly results of the CALSIM II model.

Schematic presentation of the physical components of the system and their relationship to the input and output water quantities balance in the CALSIM II model is presented in Figure 4-2. A list with the description of the nodes shown in the schematic is provided in Table 2-1

The CALSIM II model simulated future operation of the Stanislaus River taken into consideration the following assumptions:

- Maximum allocation of water to OID and SSJID per the 1988 Agreement and Stipulation between the U.S. Bureau of Reclamation (USBR) and the Districts.
- Obligations by OID and SSJID under the Vernalis Adaptive Management Plan (VAMP) and the San Joaquin River Agreement (SJRA).
- Water sale by OID and SSJID to the SEWD[1]
- Fish release requirements per the Interim Operations Plan (IOP) between the U.S. Bureau of Reclamation (USBR), the California Department of Fish and the U.S. Fish and Wildlife Service.
- Other release requirements for water quality, Bay-Delta and flood control.

Because of input data limitations, the CALSIM II model results were available only for the period WY 1922 through 1994. This presented somewhat a limitation on the analysis, as it didn't cover the storage recovery period at new Melones during WY 1995 and 1996. As such, the simulated period 1983 to 1994 was extended with two synthetic years of hydrology, as follows: WY 1938 was used for 1995 and WY 1974 was used for 1996. The synthetic water years 1938 and 1974 were selected because of their similar of magnitude of inflow and monthly distribution of inflow to New Melones to 1995 and 1996, as demonstrated in Figure 4-3.

Other assumptions related to the CALSIM II data were:

- The monthly flow data were distributed evenly throughout the month to derive the daily values.
- New Melones withdrawals were adjusted such that Tulloch Storage volume ranges between 57 and 67 TAF, in accordance with the flood control requirements.

[1] Although the sale of water by OID and SSJID to the SEWD was not explicitly modeled, it was implicitly modeled by the fact that both OID and SSJID were assumed to be making full use of their allocation. Therefore, from a mass-balance point of view, the sale of water to SEWD is already accounted for in the districts total diversion.

- New Melones evaporation rates were scaled such that minimum New Melones storage volume equals 69 TAF
- Return flows to the Lower Stanislaus River were not considered due to the fact that CALSIM II results appear to overestimate those values.

Figure 4-1 New Melones Storage Cycle in the Period 1983-1996

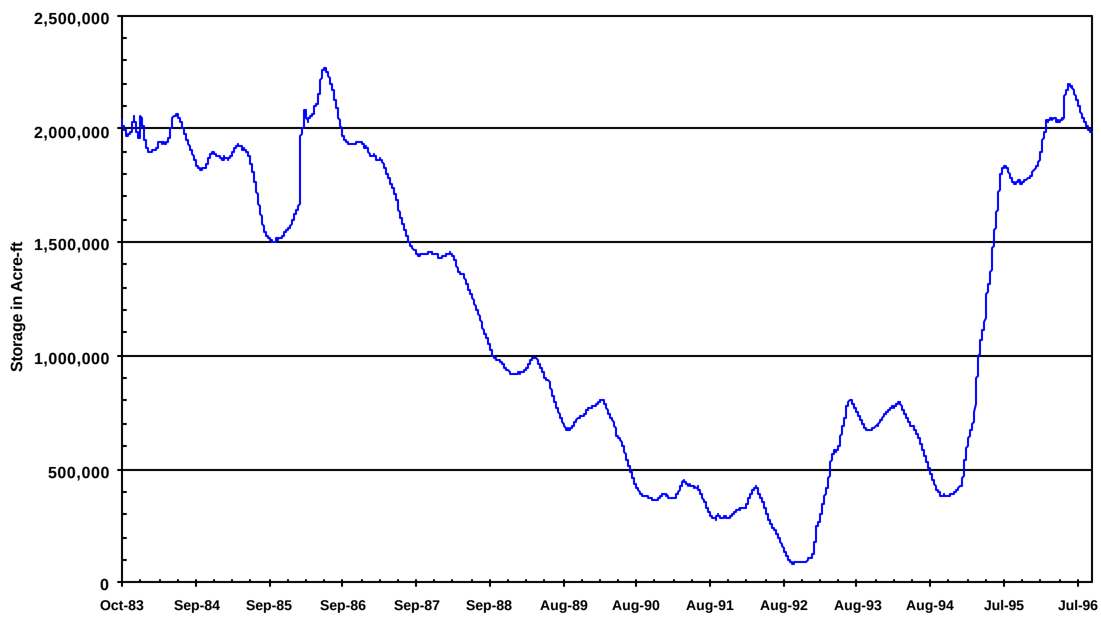


Figure 4-2 CALSIM II Schematic

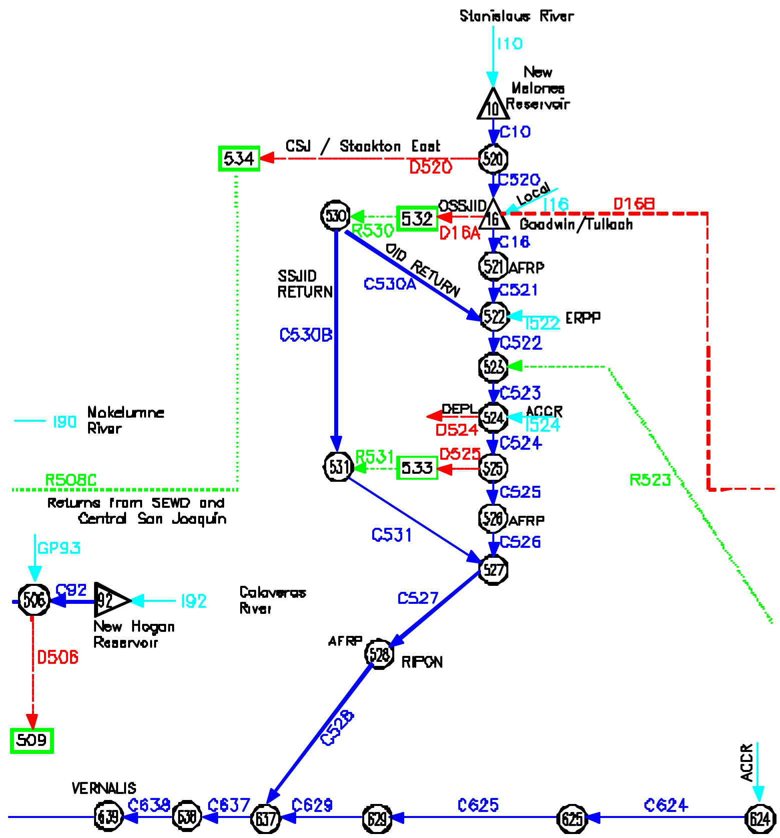
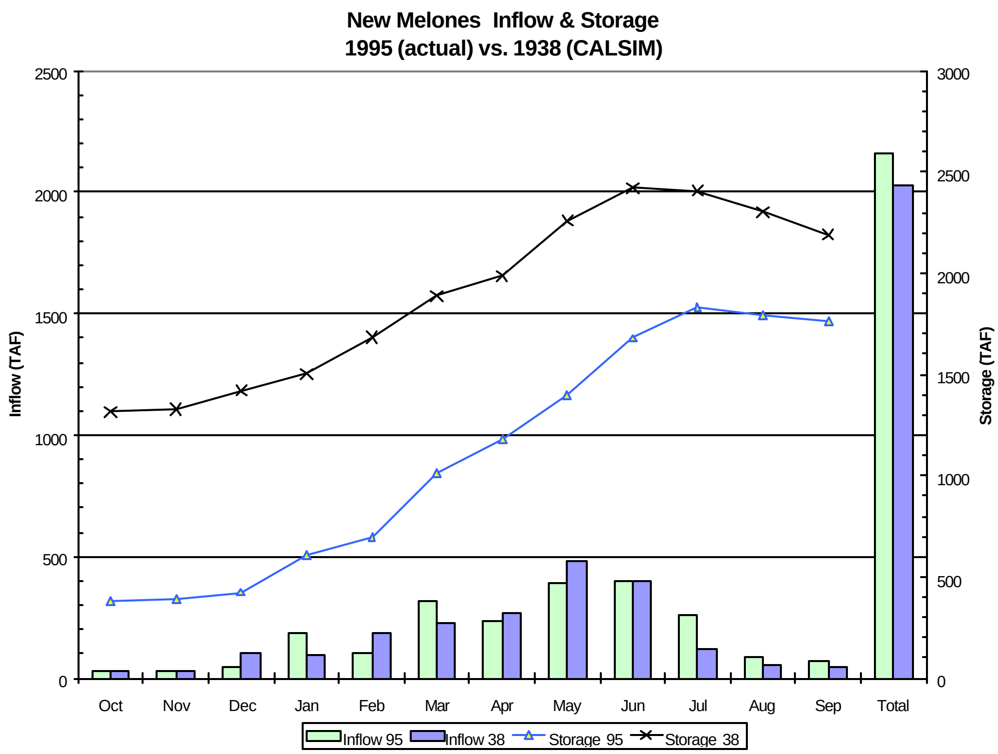
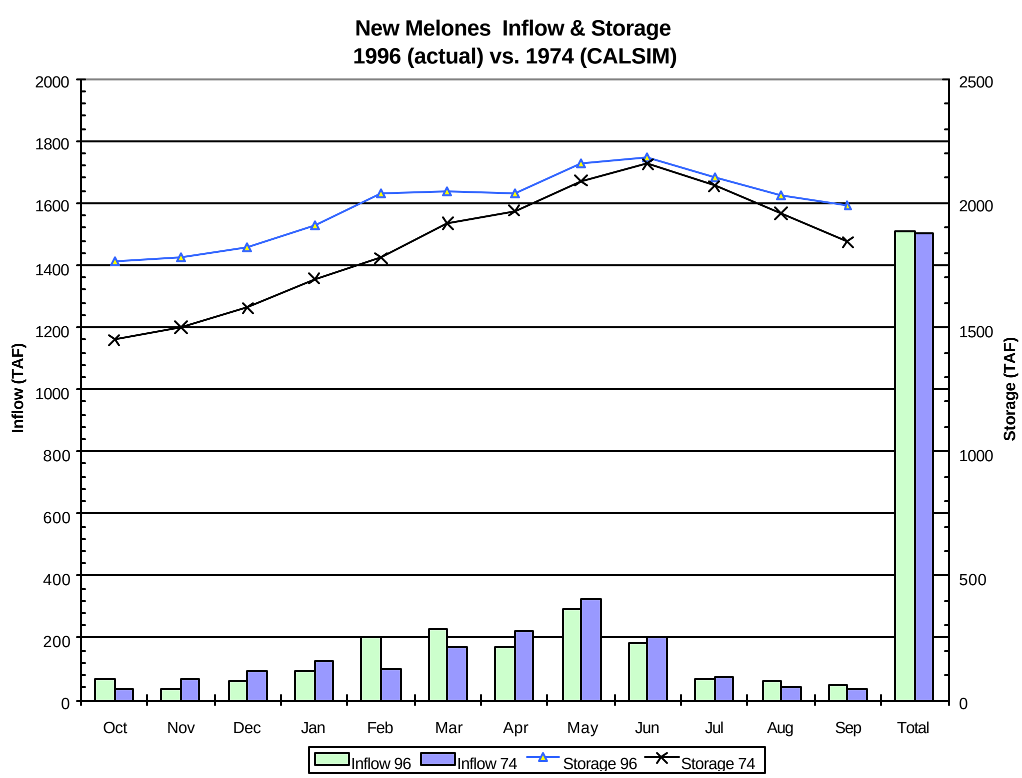


Table 4-1 A list of the nodes in CALSIM II Schematic

Node	Description
S10	New Melones Storage
S16	Goodwin/Tulloch Storage
I10	New Melones Inflow
D10	CVP Export
C10	Channel Flow Below New Melones
D520	CSJ/SEWD Deliveries
C520	Cannel Flow
I16	Local Inflows
D16A	OID/SSJID Deliveries
D16B	Other Deliveries
C16	Channel Flow Below Goodwin
C521	Channel Flow next Reach Downstream
C530A	OID Return Flow Into Stanislaus
C522	Channel Flow next Reach Downstream
R523	Return Flows From South of Stanislaus River
C523	Channel Flow next Reach Downstream
D524	Depletion from Channel
I524	Accretion to Channel
C524	Channel Flow next Reach Downstream
D525	Depletion from Channel
C525	Channel Flow next Reach Downstream
C526	Channel Flow next Reach Downstream
C531	SSJID Return Flows from North of Stanislaus River
C527	Channel Flow Above Ripon
C528	Channel Flow to Confluence with San Joaquin River

Figure 4-3 Selection of Synthetic Years for CALSIM II Model Extension





4.3 TEMPERATURE OBJECTIVES

Temperature objectives were the diving force behind the Operations Study. The temperature objectives were defined by the California Department of Fish and Game who classified three criteria for daily average water temperatures: Optimal, sub-lethal and critical. The criteria were defined separately for fall-run Chinook salmon and for Steelhead Rainbow trout. The temperatures varied by location on the Stanislaus River and by month. Detailed description of how the water temperature criteria were developed is provided in the Appendix and summarized in Table 4-2 below:

Table 4-2 Clarification of Water Temperature Criteria.

Temperature Criteria for Steelhead Trout

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp. Criteria/location	KF	KF	OAK	OAK	OAK	OAK	OAK	OAK	OAK	OAK	OAK	KF
Optimal -Max	52	52	56	56	56	60	60	60	60	56	56	52
Sub-Lethal	52-56	52-56	56-66	56-66	56-66	60-66	60-66	60-66	60-66	56-66	56-66	52-56
Critical	56	56	66	66	66	66	66	66	66	66	66	56

Temperature Criteria for Chinook Salmon

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temp. Criteria/location	RB	RB	CON	CON	CON	CON	KF	KF	CON	RB	RB	RB
Optimal -Max	54	54	55	55	55	55	60	60	54	54	54	54
Sub-Lethal	54-62	54-62	55-65	55-65	55-65	55-65	60-65	60-65	54-65	54-65	54-62	54-62
Critical	62	62	65	65	65	65	65	65	65	65	62	62

Key:

RB	Riverbank
CON	Confluence with the SJR
KF	Knight's Ferry
OAK	Oakdale Recreation Area

The above table can be explained using the following example: If the daily average water temperature at the Oakdale Recreation Area exceeds 66 degrees F in June, it would constitute critical (or lethal) conditions for Steelhead trout. If the temperature exceeds 65 degrees F, it would constitute critical (or lethal) conditions for Chinook salmon. If water temperature were between 60 and 66 degree F, it would constitute sub-lethal conditions for Steelhead trout. If the temperature were between 55 and 65 degree F, it would constitute sub-lethal conditions for Chinook salmon. If the temperature drops below 60 degrees F, it would constitute optimal conditions for Steelhead trout and if the temperature drops below 55 degrees F, it would constitute optimal conditions for Chinook salmon.

Accordingly, the model tracks the temperature conditions at all of the above-mentioned control points for the purpose of comparing the various operating cases described in the following section.

4.4 OPERATING CASES

The methodology in developing the operating cases was as follows:

- **Defining Base Case Conditions:**

Two base cases were considered:

1) *Historical Conditions* – This case simulated water temperature conditions in New Melones, Tulloch, Goodwin and Stanislaus River from Goodwin Dam to the confluence of the Stanislaus River with the san Joaquin River based on the historical hydrology in the period 1983 - 1996, as described in Section 4.2 above.

   The Historical Conditions Base Case was used as a reference case and for use in future analyses.

2) *Simulated Conditions* – This case simulated water temperature conditions in New Melones, Tulloch, Goodwin and Stanislaus River from Goodwin Dam to the confluence of the Stanislaus River with the san Joaquin River based on the simulated operation of the system for the period 1983 – 1996 using CALSIM II, as described in Section 4.2 above.

   The Simulated Conditions Base Case was used as the baseline case on which all the other operating cases were built upon.

- **Defining Temperature Objectives:**

Two temperature objectives were considered:

1) *For Steelhead Rainbow Trout* – Using temperature criteria provided by the CDF&G as discussed in Section 4.3 above.
2) *For Fall-Run Chinook Salmon* – Using temperature criteria provided by the CDF&G as discussed in Section 4.3 above.

- **Defining Mechanisms for Temperature Improvements:**

Four types of mechanisms for temperature improvements were considered:

1) *Storage Allocation* – Allocating up to 50 TAF of volume of water at New Melones every year towards improvements of water temperature conditions for Steelhead trout.
2) *Minimum Pool* – Maintaining minimum pool in New Melones of 350 TAF.
3) *Operations Changes* – Bypassing New Melones powerplant by releasing water through the low-level outlet, or alternatively, blending New Melones powerplant flow with water from the low-level outlet.
4) *Physical Improvements* – Constructing a temperature control device in New Melones. Constructing a new low-level outlet at Goodwin Dam.

Given the above-mentioned parameters, a list of eleven different alternatives for operating cases was compiled as shown in Table 4-3.

Table 4-3 Operating Cases

#	Run	Description	Hydrology	Temperature Objective	Mechanism
1	Run 1	Reference case	Historical Conditions	NA	NA
2	Run 2	Base Run	Simulated Conditions	NA	NA
3	Run 3a	Allocating 50 TAF to meet Steelhead Objectives	Simulated Conditions	Steelhead	Storage Allocation
4	Run 3b	Allocating 50 TAF to meet Steelhead Objectives and low-level release in 1992	Simulated Conditions	Steelhead	Storage Allocation and Operations Changes
5	Run 4	Re-operating New Melones with minimum pool of 350 TAF	Simulated Conditions	NA	Minimum Pool
6	Run 5	Re-operating New Melones using existing outlet works	Simulated Conditions	Steelhead	Operations Changes
7	Run 6	Re-operating New Melones using existing outlet works	Simulated Conditions	Chinook	Operations Changes
8	Run 7	Constructing Temperature Control Device	Simulated Conditions	Steelhead	Physical Improvements
9	Run 8	Constructing Temperature Control Device	Simulated Conditions	Chinook	Physical Improvements
10	Run 9	Operating Goodwin Pool using low-level outlet	Simulated Conditions	NA	Physical Improvements
11	Run 10	Re-operating New Melones using existing outlet works and operating Goodwin Pool using low-level outlet	Simulated Conditions	NA	Operations Changes and Physical Improvements

Some assumptions associated with the operating cases are summarized below:

Run 1 - Historical

- Daily flow, meteorology, volumes, inflow temperatures, etc. as described in Section 4.2 above for Historical Conditions.

Run 2 - Baseline (all the remaining cases use these assumptions)

- Daily flow, meteorology, volumes, inflow temperatures, and adjustments as described in Section 4.2 above for Simulated Conditions.

Run 3a - Allocating 50 TAF for Steelhead

- River flow augmentation begin when temperature is within 2 degrees F of critical unless New Melones discharge temperature would be > 60 degrees F.
- Flow taken from storage if beginning-of-year New Melones volume > 1,000 TAF.
- Steelhead flow recovered for subsequent excess inflow (in 1985 only).
- Deliveries cut back 50 TAF if beginning-of-year New Melones volume < 1,000 TAF (50 TAF used for flow augmentation with excess retained in New Melones).
- Flow augmentation for steelhead and resulting curtailed deliveries are presented in Table 4-4.

Table 4-4 Flow Augmentation for steelhead and resulting curtailed deliveries under Run 3a.

Year	Steelhead flow volume	Make-up volume	Curtailed deliveries	Deliveries to storage	Flow through low-level outlet	End-of-year storage change	End-of-year elevation	Baseline end-of-year elevation
	AF	AF	AF	AF	AF	AF	FT	FT
1983	0	0	0	0	0	0	1049.0	1049.0
1984	4,760	0	0	0	0	-4,760	1027.7	1028.2
1985	0	4,760	0	0	0	0	980.2	980.2
1986	0	0	0	0	0	0	1039.8	1039.8
1987	0	0	0	0	0	0	973.9	973.9
1988	6,490	0	50,000	43,510	0	43,510	935.5	929.5
1989	0	0	50,000	50,000	0	93,510	926.0	912.6
1990	10,330	0	50,000	39,670	0	133,180	884.7	860.9
1991	29,090	0	50,000	20,910	0	154,090	853.1	819.5
1992	3,300	0	50,000	46,700	0	200,790	804.8	731.0
1993	3,480	0	0	0	0	197,310	933.8	908.0
1994	0	0	0	0	0	197,310	901.8	872.2
1995	0	0	0	0	0	197,310	979.4	959.0
1996	0	0	0	0	0	197,310	1013.9	996.1

Run 3b - Allocating 50 TAF for Steelhead plus low-level release in 1992

- Similar to Run 3a above except that in 1992 water from New Melones is released through the low-level outlet in order to eliminate completely critical water temperatures (see Section 4.5).
- Flow augmentation for steelhead and resulting curtailed deliveries are presented in Table 4-5.

Table 4-5 Flow Augmentation for steelhead and resulting curtailed deliveries under Run 3b.

Year	Steelhead flow volume	Make-up volume*	Curtailed deliveries	Deliveries to storage	Flow through low-level outlet**	End-of-year storage change	End-of-year elevation	Baseline end-of-year elevation
	AF	AF	AF	AF	AF	AF	FT	FT
1983	0	0	0	0	0	0	1049.0	1049.0
1984	4,760	0	0	0	0	-4,760	1027.7	1028.2
1985	0	4,760	0	0	0	0	980.2	980.2
1986	0	0	0	0	0	0	1039.8	1039.8
1987	0	0	0	0	0	0	973.9	973.9
1988	6,490	0	50,000	43,510	0	43,510	935.5	929.5
1989	0	0	50,000	50,000	0	93,510	926.0	912.6
1990	10,330	0	50,000	39,670	0	133,180	884.7	860.9
1991	29,090	0	50,000	20,910	0	154,090	853.1	819.5
1992	8,760	0	50,000	41,240	130,000	195,330	804.8	731.0
1993	3,480	0	0	0	0	191,850	933.8	908.0
1994	0	0	0	0	0	191,850	901.8	872.2
1995	0	0	0	0	0	191,850	979.4	959.0
1996	0	0	0	0	0	191,850	1013.9	996.1

* Make-up volume during May 1985

** temperature target of 56 F for July - November

Run 4 - Maintaining minimum New Melones pool of 350 TAF (see Table 4-6)

- Curtail deliveries to meet minimum pool of 350 TAF in Oct. 30, 1992.
- Reduce Goodwin diversions by 20 % during 1990 – 1992.

Table 4-6 Curtailment of deliveries needed in order to maintain minimum pool of 350 TAF in New Melones in October 30, 1992.

Year	Baseline Deliveries	Deliveries after Curtailment	Deliveries to Storage	End-of-year Storage**	Baseline end-of-year Storage	End-of-year Elevation	Baseline end-of-year Elevation
	TAF	TAF	TAF	TAF	TAF	FT	FT
1983	574.0	574.0	-	1,981.0	1,981.0	1,049.0	1,049.0
1984	585.0	585.0	-	1,772.7	1,772.7	1,028.3	1,028.2
1985	579.4	579.4	-	1,329.7	1,329.7	980.3	980.2
1986	571.2	571.2	-	1,887.3	1,887.3	1,039.8	1,039.8
1987	505.0	505.0	-	1,274.1	1,274.1	973.9	973.9
1988	438.7	438.7	-	930.7	930.7	929.5	929.5
1989	571.0	571.0	-	817.8	817.8	912.9	912.6
1990	501.6	402.6	99.1	614.6	517.0	879.6	860.9
1991	507.5	407.3	100.2	525.8	332.4	862.9	819.5
1992	483.9	388.3	95.6	375.6	95.3	830.4	731.0
1993	571.3	571.3	-	1,061.7	788.2	947.1	908.0
1994	501.8	501.8	-	843.6	576.8	916.7	872.2
1995	573.0	573.0	-	1,414.2	1,152.8	990.1	959.0
1996	574.0	574.0	-	1,724.5	1,468.0	1,023.4	996.1

** 350 TAF minimum pool (October 30, 1992)

Run 5 - Re-operating New Melones for steelhead using existing outlet works

- Blend Low-level outlet releases with power outlet for steelhead temperature criteria.
- Control temperature using the temperature targets shown in Figure 4-4.

Run 6 - Re-operating New Melones for salmon using existing outlet works

- Blend Low-level outlet releases with power outlet for salmon temperature criteria.
- Control temperature using the temperature targets shown in Figure 4-4.

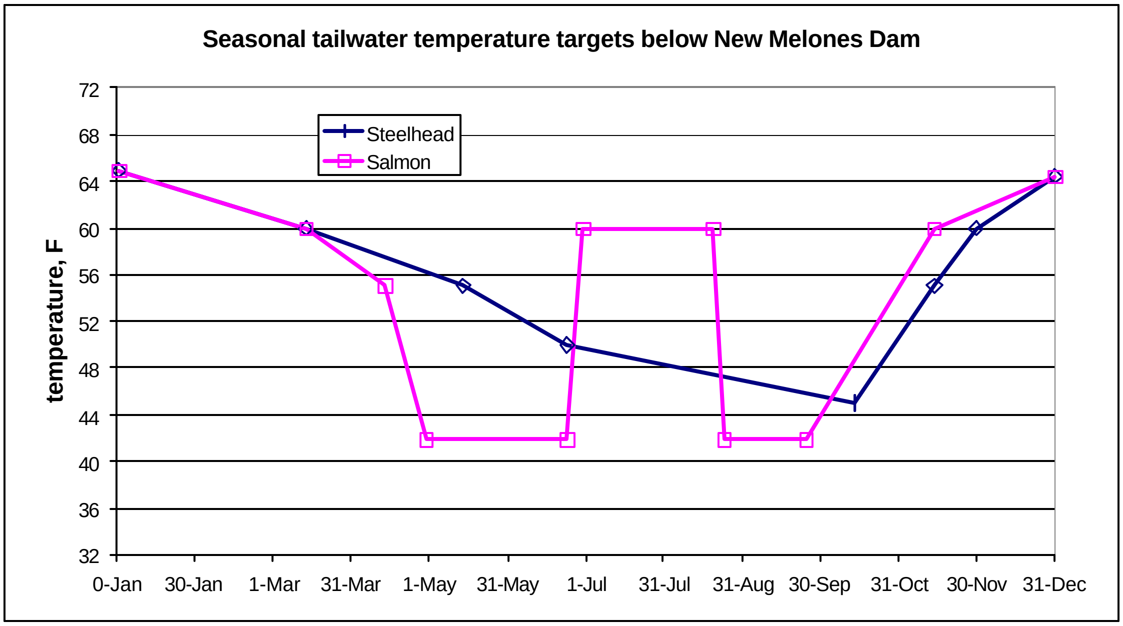
Run 7 - Constructing Temperature Control Device (operating for steelhead)

- New Melones Dam with temperature control structure with withdrawal capabilities between 725 and 950' elevation.
- Control temperature using the temperature targets for steelhead as shown in Figure 4-4.

Run 8 - Constructing Temperature Control Device (operating for salmon)

- New Melones Dam with temperature control structure with withdrawal capabilities between 725 and 950 feet elevation.
- Control temperature using the temperature targets for salmon as shown in Figure 4-4.

Figure 4-4 Temperature Control Targets



Run 9 - Goodwin Dam Retrofit

- Provide an outlet with a capacity of 300 cfs at the bottom of Goodwin Dam.

Run 10 - Goodwin Dam Retrofit plus low-level outlet of New Melones Dam for blending with power flows

- Provide an outlet with a capacity of 300 cfs at the bottom of Goodwin Dam.
- Control temperature using the temperature targets for salmon as shown in Figure 4-4.

4.5 RESULTS OF THE OPERATING CASES

The results of the operating cases are presented in terms of duration of water temperature conditions and cumulative degree-days of violation of critical temperature conditions in the Stanislaus River at key location points identified by the CDFG.

Figure 4-5 is an example duration table for water temperature condition at the key location points in the system. In this example, the duration table shows the percent of the time optimal, sub-optimal and critical temperature conditions for Chinook salmon occur in the specified points.

Figure 4-6 is an example plot showing the cumulative violation in degree-days of water temperature conditions with respect to the critical threshold for Chinook salmon and Steelhead trout under a given operating scenario.

Figure 4-7 is an example duration table for Goodwin release and New Melones storage under a given operating scenario.

A summary of the results is presented in Figure 4-8 below. Detailed duration tables and water temperature violation plots for all the cases in the operations study are provided in the Appendix as well as ranking of the runs in accordance with the magnitude of temperature duration and violation.

Figure 4-5 Temperature duration table for Chinook salmon.

% of time Temp. is equaled to or less	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
5%	43.7	45.5	50.7	54.7	56.8	59.2	52.3	52.6	63.7	52.0	46.0	43.2
10%	44.1	46.6	52.5	55.6	58.4	59.9	52.6	53.9	65.0	53.4	47.1	43.8
15%	44.7	47.8	53.6	56.5	59.2	63.8	53.0	54.0	66.1	54.0	48.9	44.5
20%	45.2	48.6	54.0	57.1	59.6	64.6	53.3	54.1	66.8	54.3	49.9	45.3
25%	45.7	48.9	54.7	57.9	60.2	65.3	53.6	54.4	67.6	54.7	50.7	45.8
30%	45.9	49.1	55.1	58.4	60.7	65.7	53.9	54.6	68.5	55.3	51.5	46.0
35%	46.4	49.4	55.7	59.0	61.4	66.2	54.2	54.9	69.1	55.8	51.9	46.7
40%	46.7	49.7	56.2	59.4	62.1	66.7	54.7	55.1	69.8	56.2	52.4	47.2
45%	47.1	49.9	57.0	59.9	62.7	67.2	54.8	55.7	70.4	57.5	52.7	47.8
50%	47.3	50.4	58.1	60.4	63.1	67.7	55.1	56.0	71.0	59.5	53.4	48.6
55%	47.6	50.8	58.8	61.0	63.6	68.2	55.4	56.4	71.5	61.5	53.8	49.4
60%	47.9	51.5	59.6	61.6	64.1	68.6	55.7	56.8	71.8	62.3	54.4	49.7
65%	48.1	51.9	60.4	62.1	64.4	69.5	56.0	57.0	72.2	63.4	54.9	50.3
70%	48.4	52.2	61.2	62.8	64.9	70.0	56.2	57.3	72.5	64.0	55.2	50.6
75%	48.6	52.7	61.9	63.2	65.6	70.5	56.4	57.5	72.9	64.8	55.7	50.9
80%	48.9	53.1	62.5	63.8	66.3	70.9	56.6	57.8	73.8	65.5	56.2	51.2
85%	49.4	53.8	63.1	64.3	66.9	71.3	57.0	58.7	74.4	65.9	57.0	51.5
90%	50.3	54.6	63.9	64.7	67.6	72.3	57.7	61.8	75.7	66.4	58.4	52.2
95%	51.3	56.2	65.3	66.2	68.5	74.0	60.3	64.3	76.2	69.9	60.1	52.8
100%	53.8	59.7	69.4	67.9	72.4	77.1	66.2	69.2	77.3	74.6	63.9	54.6
Temp. Criteria/location	RB	RB	CON	CON	CON	CON	KF	KF	CON	RB	RB	RB
Optimal -Max	54	54	55	55	55	55	60	60	54	54	54	54
Sub-Lethal	54-62	54-62	55-65	55-65	55-65	55-65	60-65	60-65	54-65	54-65	54-62	54-62
Critical	62	62	65	65	65	65	65	65	65	65	62	62
Optimal (%)	100%	85%	25%	5%	0%	0%	90%	85%	0%	15%	55%	95%
Sub-Lethal (%)	0%	15%	65%	85%	70%	20%	5%	10%	10%	60%	40%	5%
Critical (%)	0%	0%	10%	10%	30%	80%	5%	5%	90%	25%	5%	0%

Key:

RB	Riverbank
CON	Confluence with the SJR
KF	Knight's Ferry
OAK	Oakdale Recreation Area
	Optimal Temperature conditions
	Sub-Lethal Temperature conditions
	Critical Temperature conditions

Figure 4-6 Water temperature violation.

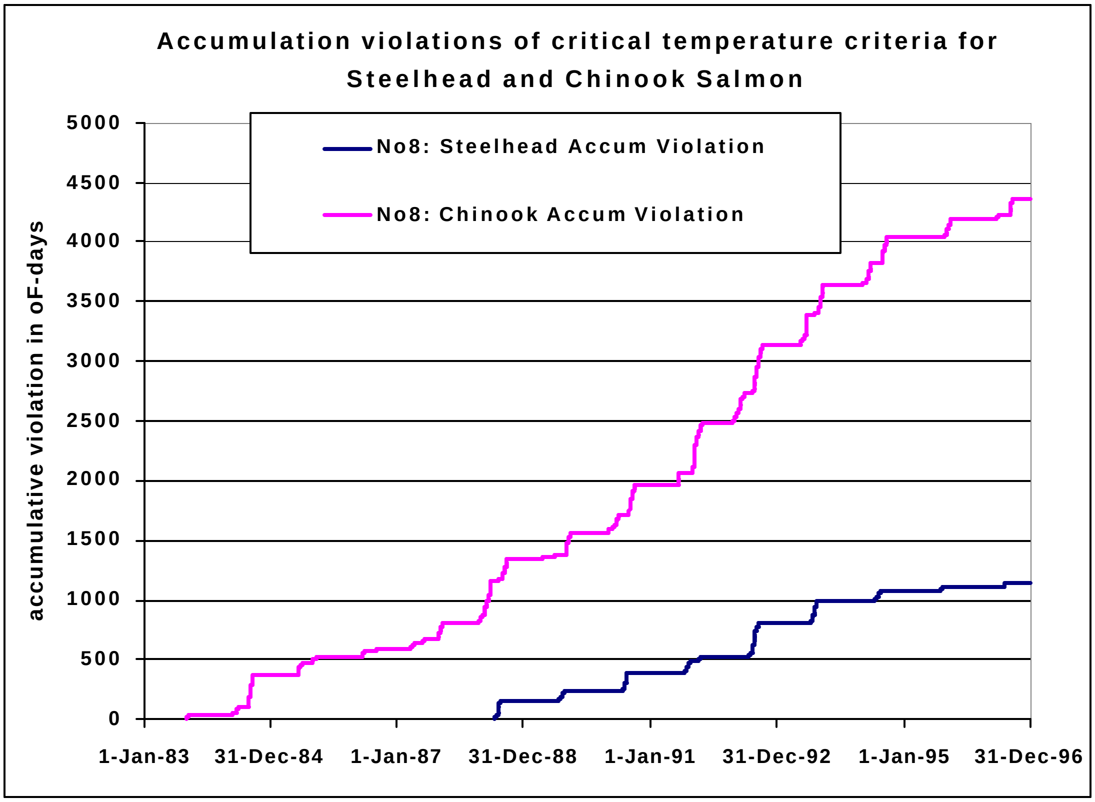


Figure 4-7 Goodwin Release and New Melones duration tables.

Run 10

Re-operating New Melones using existing outlet works and operating Goodwin using a new low-level outlet

Goodwin Dam Release (cfs)

% of time Release is equaled to or less	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0%	124	124	124	380	496	255	265	283	249	109	198	198
5%	124	124	124	380	496	255	265	283	249	109	198	198
10%	124	124	124	380	496	326	377	283	249	109	198	198
15%	124	124	124	380	496	399	421	283	249	109	198	198
20%	124	124	124	380	496	399	421	283	249	109	198	198
25%	124	124	124	408	496	528	444	287	249	109	198	198
30%	126	126	124	412	514	529	484	325	249	109	198	198
35%	126	126	124	412	514	529	484	325	249	109	198	198
40%	128	128	126	493	554	638	498	341	249	110	201	201
45%	221	251	157	572	570	655	551	384	249	110	203	203
50%	221	251	157	572	570	655	551	384	249	110	203	203
55%	251	274	251	859	1,033	759	625	462	249	350	251	251
60%	274	290	274	939	1,479	798	629	527	300	350	274	274
65%	290	350	369	1,498	1,500	809	629	527	337	350	350	350
70%	290	350	369	1,498	1,500	809	629	527	337	350	350	350
75%	350	401	401	1,498	1,500	825	675	564	401	352	369	369
80%	401	578	1,334	1,498	1,500	831	893	716	401	446	401	401
85%	401	578	1,334	1,498	1,500	831	893	716	401	446	401	401
90%	2,629	2,376	2,962	1,498	1,500	1,639	899	770	481	3,834	425	544
95%	4,150	4,745	5,460	1,498	1,500	4,034	2,390	893	968	5,498	3,298	4,687
100%	4,150	4,745	5,460	1,498	1,500	4,034	2,390	893	968	5,498	3,298	4,687

New Melones Storage (TAF)

% of time Storage is equaled to or less	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0%	101	269	380	421	329	246	170	104	72	69	69	72
5%	210	339	424	440	389	301	219	146	93	71	70	87
10%	339	375	447	546	531	481	410	335	294	290	303	318
15%	517	522	533	561	592	670	575	497	463	464	491	497
20%	521	527	561	570	686	700	609	534	485	488	495	512
25%	618	752	868	854	771	726	641	556	506	491	513	553
30%	796	837	877	871	802	746	776	714	678	680	714	749
35%	820	847	888	893	839	796	799	760	699	703	738	782
40%	830	857	960	1,042	1,017	964	885	803	754	757	781	805
45%	933	944	1,003	1,078	1,189	1,123	1,048	993	952	937	930	929
50%	938	1,273	1,050	1,144	1,234	1,179	1,100	1,028	979	941	935	931
55%	1,232	1,287	1,304	1,294	1,329	1,537	1,493	1,377	1,313	1,286	1,152	1,153
60%	1,277	1,302	1,410	1,516	1,592	1,601	1,534	1,416	1,328	1,288	1,280	1,275
65%	1,338	1,445	1,832	1,830	1,693	1,644	1,555	1,451	1,376	1,295	1,292	1,309
70%	1,393	1,781	1,860	1,850	1,750	1,672	1,581	1,504	1,417	1,315	1,304	1,325
75%	1,780	1,815	1,897	1,868	1,794	1,687	1,647	1,549	1,465	1,433	1,438	1,456
80%	1,884	1,884	1,917	1,976	1,957	1,931	1,849	1,750	1,701	1,695	1,704	1,742
85%	1,887	1,888	1,986	2,031	1,962	1,951	1,911	1,818	1,728	1,696	1,731	1,769
90%	1,970	1,970	2,004	2,035	2,074	2,108	2,071	1,964	1,887	1,861	1,869	1,882
95%	1,981	1,981	2,023	2,063	2,088	2,245	2,425	2,370	2,299	2,058	1,981	1,981
100%	1,981	1,982	2,062	2,066	2,168	2,424	2,426	2,424	2,349	2,270	1,981	1,981

Figure 4-8 Summary Results.

Stanislaus River Water Temperature Model
Summary of Operations Study

% of the time temperature objectives are achieved
Accumulative temperature violation in degree F (with respect to critical conditions)

			Steelhead					Chinook				
#	Run	Description	Optimal	Sub-Lethal	Sub Lethal	Critical	Violations deg F-day	Optimal	Sub-Lethal	Sub Lethal	Critical	Violations deg F-day
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Run 1	Historical Conditions (WY: 1983-1996)	59%	30%	89%	11%	1,445	46%	33%	79%	21%	5,650
2	Run 2	Simulated Base Case	65%	31%	96%	4%	534	46%	32%	78%	22%	4,467
3	Run 3a	Allocating up to 50 TAF to Meet Steelhead Objectives	67%	31%	98%	3%	264	48%	32%	80%	20%	3,972
4	Run 3b	Allocating up to 50 TAF to Meet Steelhead Objectives + Low Level Release in 1992	67%	33%	100%	0%	-	48%	33%	80%	20%	3,806
5	Run 4	Re-operating New Melones with minimum pool of 350 TAF	68%	30%	97%	3%	157	49%	31%	80%	20%	4,138
6	Run 5	Re-operating New Melones for Steelhead Objectives using existing outlet works	66%	30%	96%	4%	444	48%	32%	79%	21%	4,346
7	Run 6	Re-operating New Melones for Chinook Objectives using existing outlet works	66%	30%	97%	3%	442	48%	31%	79%	21%	4,238
8	Run 7	Re-operating New Melones for Seelhead using a new Temperature Control Device	55%	41%	96%	4%	344	50%	26%	76%	24%	5,145
9	Run 8	Re-operating New Melones for Chinook using a new Temperature Control Device	58%	33%	91%	9%	1,146	39%	38%	77%	23%	4,368
10	Run 9	Operating Goodwin using a new low-level outlet	68%	29%	96%	4%	474	46%	32%	78%	22%	4,312
11	Run 10	Re-operating New Melones using existing outlet works and operating Goodwin using a new low-level outlet	69%	28%	97%	3%	384	48%	32%	80%	20%	4,076

5 REFERENCES

Hydrologic Engineering Center (HEC). 1999b. "Water Quality Modeling of Reservoir System Operations Using HEC-5, Training Document", Davis, CA.

Hydrologic Engineering Center (HEC). 2000. "HEC-5, Simulation of Flood Control and Conservation Systems, Appendix on Water Quality Analysis", Davis, CA.

Jason Guignard, January 17, 2001. Stanislaus River Temperature Monitoring/Modeling Project Water Temperature Criteria Development, California Department of Fish and Game

Michael Deas, July 20, 2001. "Appraisal of the Application of HEC-5Q for Temperature Simulation of the Stanislaus River", Watercourse Engineering, Napa CA.

6 APPENDIX

Compact Disk Table of Contents

- **Stan_5Q**: Main directory contains HEC-5Q executable and final report
  - **code:** HEC-5Q FORTRAN code included as reference material
  - **documentation:** program documentation and training manual
  - **Deg-days:** Utility program and files for determing temperature violation
  - **HEC-5Q data:** HEC-5Q data sets and output for the calibration period
    - **GUI:** Graphical User Interface (GUI)
  - **Reports:** Final Report - Supporting Documents

Compact Disk Table of Contents

Directory / File	Description
Stan_5Q	**Main directory**
HEC5Q.EXE	HEC-5Q executable
Stanislaus Temperature Model Report.pdf	Project final report in PDF format
Code	**HEC-5/5Q Fortran code**
*.for	Fortran subroutines
cc.*	include statements referenced within the Fortran code
*.cal	
*.inc	
Documentation	**Users manual and support files**
ACF ACT training.doc	Training Document referencing the ACF/ACT project - included as background material only
Users Guide.doc	Users guide and supporting exhibits and figures
exhibit*.doc	
other Figures.ppt	
HEC-5Q data	**files pertaining to Stanislaus River project HEC-5Q model calibration and alternatives analysis**
*.bat	batch and run files for initiating the calibration and alternative simulations from windows.
*.r	
*.in	
stan#3.*	historical flow and/or meteorological data. The "noflow" files contain meteorological data only since daily hydrology is input via the "*.25q" for the alternative analysis
noflow.*	
*.25q	
*.dat	Input data files for model calibration and alternative analysis
*.out	ASCII output files (flow and quality) for the calibration period (example output)
*.01	GUI output files
*.xls	CDF files of stream and reservoir computed temperature and volume
running 5Q.doc	Description of file assignment procedures
HEC-5Q data\gui	**Graphical User Interface (GUI) directory**
H5QGUI.exe	executable and supporting files
*.vr	
SR.prj	project file defining map limits
*.run	run files for viewing alternative and calibration results. Calibration results are presented at 12-hour intervals and alternative results are averages over two days. (specified in the HEC-5Q data sets)
prof2k_f.*	DSS files containing reservoir profile and stream time series data
april_f.*	
*.dat	HEC-5 and HEC-5Q data sets for defining model structure
*.dlg	base map digital line graphs

Compact Disk Table of Contents (Cont.)

Degree-days	**Utility program and files for determining temperature violation**
deg-days.for F77L3.EER	Utility program Fortran code and error interpretation file
*.ts	output files created by HEC-5Q containing computed temperatures at 6-hour intervals at all location where temperature criteria are defined (moved from "HEC-5Q data" directory
*.tab	CDF file of monthly violations, reservoir volumes, compliance temperatures, etc. compatible with the temperature violation spreadsheet (program output)
*.avg	CDF file of daily average temperature and accumulative violation at the Salmon and Steelhead temperature compliance points
Reports	**Final Report - Supporting Documents**
StanislausTemperatureModelReview_7-20-01Final.doc	Model appraisal by Dr. Michael Deas, Watercourse Engineering, Inc.
scoringExample.xls	Example for scoring runs in the operations study
scoringR1.xls to scoringR10.xls	Scoring results by run showing % exceedance of temperature conditions, Goodwin release and New Melones storage
tempVioltions.xls	HEC-5Q temperature violations results for the operations study
summaryRuns.xls	Summary results of the operations study and ranking of runs
Temperature Criteria Development2.doc	Memo by the CDFG regarding the development of water temperature criteria used in the operations study
TempCriteriaChart.xls	Chart showing temperature objectives by control points (CDFG document)